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History of anti-aircraft guns

W. N. Dickinson, United States. Army. Ordnance ...

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ANTI-AIRCRAFT GUNS

By W. N. DICKINSON

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HISTORY OF ANTI-AIRCRAFT GUNS.

AN HISTORICAL RECORD OF ANTI-AIRCRAFT GUNS IN CONNECTION WITH THE EUROPEAN WAR.

By W. N. Dickinson.

This handbook is issued with the understanding that it shall at all times be given the care accorded confidential information; that no portion of it shall be published by paraphrase or otherwise, and that it shall be returned to the office of the Chief of Ordnance when the person to whom it is issued leaves the military service of the United States.

The facts have been collected from the official records, cablegrams, and reports, and have been supplemented by information obtained from officers in the several branches of the military establishment whose services were rendered both in the United States and with the American Expeditionary Forces.

C. C. Williams,
Maj. Gen., Chief of Ordnance, U. S. A.

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CONTENTS.

	Page.
Introduction	7
CHAPTER I.	
Experience of the French	11
CHAPTER II.	
Liaison of French and British	25
CHAPTER III.	
Fire control and ammunition	30
CHAPTER IV.	
Anti-aircraft artillery	34
CHAPTER V.	
Anti-aircraft machine guns	37
CHAPTER VI.	
Participation of the United States	45
CHAPTER VII.	
Cablegrams	55
CHAPTER VIII.	
Response to questionnaire	68
CHAPTER IX.	
Summary	79
CHAPTER X.	
Additional Notes	89
CHAPTER XI.	
Photographs	98

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PHOTOGRAPHS.

FIELD GUNS.

	Plate No.
American improvised anti-aircraft carriage	1
American improvised anti-aircraft carriage	2
American improvised anti-aircraft carriage	3
75-millimeter field gun, French model 1897	4
75-millimeter field gun, French model 1897	5
American troops operating American 75-millimeter improvised mount equipment for anti-aircraft service	6
American troops operating American 75-millimeter improvised mount equipment for anti-aircraft service	7
75-millimeter anti-aircraft truck mount—traveling position	8
75-millimeter anti-aircraft truck mount—firing position with gun elevated at 80°	9
75-millimeter anti-aircraft truck mount—firing position	10
Group of 75-millimeter anti-aircraft truck mounts at factory, New Britain, Conn	11
3-inch anti-aircraft auto trailer, model 1918, in factory New Britain, Conn	12
3-inch anti-aircraft auto trailer, model 1918, in factory at New Britain, Conn	13
3-inch anti-aircraft auto trailer, model 1918, at proving grounds	14
American loading 3-inch anti-aircraft gun with pedestal mount	15
3-inch anti-aircraft gun, model 1917, of seacoast type, mounted on caterpillar trailer, Aberdeen Proving Ground	16
3-inch anti-aircraft gun, model 1917, seacoast type, mounted on four-wheel truck—in transport position	17
3-inch anti-aircraft gun, model 1917, seacoast type	18
4.7-inch anti-aircraft gun, model 1918, mounted on caterpillar trailer	19
4.7-inch anti-aircraft gun, model 1918, mounted on caterpillar trailer	20
4.7-inch anti-aircraft gun, model 1918, mounted on caterpillar trailer	21
75-millimeter anti-aircraft auto cannon, made in France	22
40-millimeter Vickers 2-pounder anti-aircraft gun, forwarded from England to be tested at Aberdeen Proving Ground	23
40-millimeter Vickers 2-pounder anti-aircraft gun mounted on trailer—side view	24
40-millimeter Vickers 2-pounder anti-aircraft gun mounted on trailer—rear view	25
Canadian anti-aircraft gun mounted on autotruck in action	26
English 3.6-inch anti-aircraft gun on caterpillar trailer mount	27
75-millimeter anti-aircraft auto cannon mounted on trailer with crew	28
German 37-millimeter revolving cannon, mounted on two-wheel cart, with props, for anti-aircraft service	29
German 37-millimeter revolving cannon for anti-aircraft service	30
German 37-millimeter automatic cannon for anti-aircraft service	31
German 37-millimeter automatic cannon for anti-aircraft service	32
German truck used for transporting semifixed 88-millimeter gun for anti-aircraft service	33

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	Plate No.
German semifixed mount for 88-millimeter gun for anti-aircraft service	34
German semifixed mount for 88-millimeter gun for anti-aircraft service	35
German automobile mount for 77-millimeter gun for anti-aircraft service	36
German automobile mount for 77-millimeter gun for anti-aircraft service	37
German trailer mount for 88-millimeter gun for anti-aircraft service	38
German trailer mount for 88-millimeter gun for anti-aircraft service	39
German 88-millimeter anti-aircraft guns mounted on trailers	40
Captured German 88-millimeter anti-aircraft gun mounted on trailer	41
Rear view of captured German 88-millimeter anti-aircraft gun mounted on trailer	42
German transformed 75-millimeter field gun, French model 1897, rebored to 77 millimeters	43
German transformed 75-millimeter field gun, French model 1897, rebored to 77 millimeters	44
German transformed 75-millimeter field gun, French model 1897, rebored to 77 millimeters	45
German transformed 75-millimeter field gun, French model 1897, rebored to 77 millimeters	46
German 100-millimeter gun used for anti-aircraft service	47
German, Poutiloff (?), Russian 76.2-millimeter gun, used for anti-aircraft service	48
German, Poutiloff (?), Russian 76.2-millimeter gun, used for anti-aircraft service	49
German, Poutiloff (?), Russian 76.2-millimeter gun, used for anti-aircraft service	50
Diagram to show distinctive markings of airplanes as used in present war, 1918	51
The stadia, Peycru, complete and separate view illustrating appearance of aircraft as viewed through the stadia	52
Officer approximating distance of airplane by means of the stadia	53
Altitude board, model of 1917, for goniometer	54
Goniometer and altitude board	55
Altitude telemeter, French type—front view	56
Altitude telemeter, French type—rear view	57
Starting with the tachyscope	58
Corrector V. C.—observer's station instrument	59
Corrector V. C.—central station instrument	60
Corrector V. C.—central station instrument	61
American gunner in second-line defenses, Montdidier front, firing at German airplanes	62

MACHINE GUNS.

Hotchkiss machine gun with P. B. sight mounted on upper part of Hotchkiss service tripod	63
Hotchkiss machine gun, strip fed, service sight, on mount	64
Browning machine gun, water-cooled, with service tripod and service sight	65
Hotchkiss machine gun with service sight, mounted on rim of wagon wheel	66
Hotchkiss machine gun mounted on rear of horse cart	67
Anti-aircraft improvised post mount, assembled	68

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Plate No.

Omnibus tripod, model 1915, with anti-aircraft adapter and Hotchkiss machine gun ---- 69
Hotchkiss machine gun, strip fed, mounted in trenches ---- 70
Browning machine gun, model of 1917, on Cygnet tripod with service sight ---- 71
Anti-aircraft post of 304th Machine-Gun Battalion at Raucourt, Ardennes, France ---- 72
Browning machine gun, model of 1917, with service sight, mounted on Cygnet tripod ---- 73
Omnibus tripod, model 1915, with special anti-aircraft high adapter for anti-aircraft machine-gun battalions ---- 74
Anti-aircraft machine-gun high tripod, Goetzenberger type ---- 75
Anti-aircraft machine-gun, American Expeditionary Forces, high tripod, with anti-aircraft adapter ---- 76
Anti-aircraft, machine-gun, American Expeditionary Forces, high tripod, with anti-aircraft adapter ---- 77
Anti-aircraft, machine-gun, American Expeditionary Forces, high tripod, with anti-aircraft adapter ---- 78
Anti-aircraft improvised post mount as used with Marlin tank machine gun ---- 79
Anti-aircraft machine-gun telescopic tripod shown with Lewis machine gun ---- 80
Anti-aircraft machine-gun tripod, model of 1918, as used with Vickers machine gun ---- 81
Anti-aircraft machine-gun telescopic tripod as used with Browning automatic rifle ---- 82
Anti-aircraft machine-gun tripod, model 1918, as used with Browning machine gun ---- 83
Browning automatic rifles arranged in pair and with crossbar simultaneously operating both triggers, on post mount for anti-aircraft fire ---- 84
Marlin aircraft machine guns arranged in pair and mounted on anti-aircraft machine-gun high tripod with special head ---- 85
Marlin aircraft machine guns arranged in pair for anti-aircraft fire—top view ---- 86
Marlin aircraft machine guns arranged in pair for anti-aircraft fire—side view ---- 87
Marlin aircraft machine guns arranged in pair for anti-aircraft fire—side view ---- 88
Anti-aircraft machine-gun mounts, Cygnet type, on trailer with ammunition trailer ---- 89
Anti-aircraft machine-gun mount, Cygnet type, on trailer with ammunition trailer ---- 90
Anti-aircraft machine-gun mount, Cygnet type, on trailer with ammunition trailer ---- 91
Anti-aircraft machine-gun trailer, model 1918, Sechler type ---- 92
Anti-aircraft machine-gun trailer, model of 1918, Sechler type—body view ---- 93
French machine gun in Alsace sector, with French, July 30, 1918 ---- 94
Diagram showing correct and incorrect sighting by means of trench sight or forward area sight for machine guns ---- 95
Peycru sight as mounted and used on Browning machine gun (water-cooled) model of 1917 ---- 96
British anti-aircraft target ---- 97

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HISTORY OF ANTI-AIRCRAFT GUNS IN CONNECTION WITH THE EUROPEAN WAR.

INTRODUCTION.

Without imagination no one would have been of much service in the anti-aircraft artillery development during the present war, save in the working out of specific problems which had been visualized and definitely stated by others. Likewise the problems presented came so rapidly, and were at such variance with familiar fields of artillery practice that the inventive faculty was stimulated, and a high order of intelligence and engineering knowledge and ability demanded.

The whole subject was new and development of the artillery matériel, the ammunition, and the fire control was necessary.

In field artillery practice, range problems had been presented in connection with mortars, howitzers, and guns which would cover almost the entire scale of elevation, but the results to be accomplished and the problems in connection with each of these weapons were quite different. The previously provided elevation of the guns was small, while the muzzle velocity of some of the howitzers and all of the mortars was comparatively low, and the traverse of all three of the weapons was limited. The target was usually stationary, and maps were available for establishing its position and ample time was available in which to figure its range. Observation of the point of fall of one shot would serve as a guide in correcting the range for the next shot. Frequently it was possible to choose the atmospheric conditions under which the weapon would be employed and assisting or opposing longitudinal windage, or drift-age due to side windage, could be calculated with the aid of wind gauges.

For anti-aircraft service the problem is entirely different. The single weapon must be able to cover the elevations of all three of the field artillery weapons and preferably have a traverse of 360°. These wide variations in elevation introduced serious recoil problems, and the difference in the traverse problem may be to some extent illustrated by reference to the fact that the total traverse of the 75-millimeter French, model 1897, field gun is only 6°.

Instead of a stationary target there may be presented one whose speed is one-sixth of the speed of the projectile itself and whose

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course can in no wise be forecast by road direction or terrain formation and whose position may be at any vertical or horizontal angle. The possible altitude and speed of airplanes were increased from time to time during the war, making useless the earlier basic data to be employed in the design of protective matériel. Under certain conditions of airplane approach the range must be calculated on the instant and there is no choice as to atmospheric conditions. As the target is not stationary, range corrections are difficult to estimate by observation. While gauges may indicate the direction and force of the wind at the altitude at which they are set, they furnish no indication of air currents existing at other altitudes through which it might be necessary for the anti-aircraft projectile to pass. With the flat trajectory of a fieldpiece at but few degrees elevation, the density of atmosphere through which the projectile must pass is largely uniform, while at high angles of fire with anti-aircraft guns the projectile passes through atmospheres of different rarefications and hence different resistances to the passage of the projectile. These influences affect the trajectory of the projectile, the rate of travel of the projectile, and the time element of the burning of the fuze. It will be seen that a time-fuze setting for a given linear distance at low angle of fire will not be applicable for the same linear distance of high angle of fire both on account of variations in rate of travel due to action of gravity and to density of atmosphere and to variation in rate of fuze burning due to the rarefication of atmosphere. A clockwork fuze element may dispose of part of the difficulty. With field artillery shrapnel is employed with both a time fuze and an impact fuze, and high-explosive shell with impact fuze only, but anti-aircraft disrupting projectiles must be fitted only with time fuzes, as otherwise a projectile which has missed its aerial mark will be apt to cause damage within friendly lines through impact explosion on reaching the ground. Consideration is being given to a fuze with both time and sensitive impact element, but with a safety device to insure detonation before reaching the ground. Attention is given to the effect of anti-aircraft-gun fire upon the morale of the aviator as well as to possible physical damage to aviator or plane, and in explosive projectiles high-explosive shell has almost entirely superseded shrapnel.

As there is practically no position which is entirely free from the possibility of aircraft attack, and as there is no means of determining the direction from which such attack may come, ready mobility of anti-aircraft guns is most desirable and as opportunity to reach the target is frequently only momentary, rapidity of sighting and of firing is essential. The gunner fires at something that isn't there, in the expectation or hope that the target will reach the in-

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definite "There" at the same time as the projectile. In the case of indirect fire from a camouflaged position, he has not even had a view of the approaching plane, but must lay his gun on the basis of telephone data telephoned or otherwise transmitted from the battery commander's station. All sighting must deal with futures and the determination of the future position of a fast-moving airplane is most difficult, even when the condition is a straight line of flight at a constant speed; for the angle of approach, the altitude, and the speed must first be determined or approximated, and the corrections then applied for the calculated future position, as well as air resistance for different altitudes, deflections, and variations in the burning of the fuze. Not all flights are in a straight line or at constant speed.

While first thought would be apt to concentrate on high-angle firing, the records of two auto mounts disclose that 90 per cent of all anti-aircraft firing with these two mounts was at less than 30° elevation and that 50 per cent of this 90 per cent was at less than 20° elevation. This experience is, however, entirely too limited on which to base conclusions.

Recommendations from abroad called for elevation provision from minus 5° to plus 85°. The minus elevation is employed against tanks and ground personnel, and to assist field artillery in attack on the latter's objectives.

The anti-aircraft target may be a balloon—either stationary or towed—a dirigible or an airplane, but is most frequently the last.

Location of the position of balloons or dirigibles is comparatively simple, as compared with airplane location, owing to the size of the target and the stationary position or low speed of motion. For night fire, searchlights or other illuminating means are required and for night fire and for protective fire in thick weather sound-locating devices are also employed.

The earlier fire from anti-aircraft artillery was directed solely from the burst; that is, by firing a shot, and judging of the direction of the next shot solely by observation of the nearness to which the burst of the first shot had approximated the position of the target. In the meantime, however, the position of the target had changed. This system has given way to the use of an elaborate system of instruments, for the determination of fire in accordance with certain established principles. The story of the guns is bound very closely to the story of the ammunition and the fire control. When the complexity of the problem is considered, one wonders at the faith exhibited in the possibility of finding a solution; at the ingenuity displayed in working out the fire-control devices, and at the measure of success met with by the personnel who had in hand the development of this arm of the service.

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In the attack upon aircraft the desired end may be accomplished either by the destruction of the aircraft itself or the disabling of its occupants, in which latter case the destruction would follow. The methods adopted include destruction by incendiarism, by direct hits, by flying particles from exploding shell or shrapnel, and by shell shock. Methods of fire may involve explosive projectile from a single gun, salvos or barrage fire from a number of guns, rapid firing from pom-poms (small caliber guns, firing explosive projectiles), or from machine guns firing solid shot. Groupings of ordinary rifles have also been employed, and frequently artillerymen will try for low-flying planes with their service automatic pistols.

From a report dated January 1, 1919, from American Expeditionary Forces, subject: "Anti-aircraft machine guns," prepared by First Lieut. V. S. Henry, Office of the Chief Ordnance Officer, Engineering Division, the following is quoted:

> In considering the question of anti-aircraft machine-gun matériel it is to be remembered that the science of anti-aircraft machine gunnery has changed during the present war probably to a greater extent than that of any other branch of the service. It was unheard of at the beginning of the war, and, in consequence has grown from nothing at all to an important phase of operations. As a result matériel was constantly changing and can not be said to have reached a definite basis even at this time. The matériel was greatly affected also by the change from "position warfare" to warfare of motion: portability changing from a somewhat neglected factor to one of paramount importance.
>
> The question of anti-aircraft machine-gun matériel is complicated further by the large number of different organizations using this matériel, and the fact that practically each one has a different condition to meet. In some organizations the anti-aircraft use of the gun comes first, while in others it is of secondary importance. At the same time it is necessary to reduce to a minimum the various kinds of apparatus in use, in order that the supply and maintenance may not be unduly complicated.
>
> At the beginning of the European war, in 1914, there was no conception of the formidable part which aircraft was to play in the contest, and the development of devices for meeting this form of attack, by the time of the entrance of the United States into the war in 1917, left much to be desired.

This outline of the problems and the conditions may assist in an appreciation of the really remarkable results which were obtained by American forces in the brief time at their disposal in which to acquaint themselves with the nature of the problems and assist in the development of devices and methods with which to meet them.

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Chapter I.

EXPERIENCE OF THE FRENCH.

Before going into the details of the participation of the United States in anti-aircraft warfare, it may be well to review the experience of the French anti-aircraft artillery arm of the service.

This situation may best be presented through the following chapter from report dated January 9, 1919, received from the American Expeditionary Forces, Office of the Chief Ordnance Officer, Engineering Division, History of French Anti-aircraft Artillery Methods and Matériel, prepared by Capt. R. L. Goetzenberger, Ordnance Department, in collaboration with Lieut. Col. E. Pagezy and Capt. Paul Gassier, of the French Army:

Before 1914 no one had foreseen the formidable development of the rôle that aviation was to play in modern war, as concerns reconnaissances, fire observation, raids behind the lines, day and night bombardments.

Consequently the means of defense against air raids, particularly those of the anti-aircraft artillery were most defective. No special matériel, no established methods of fire control, no organization.

The dirigible had been considered the only means for bombing operations. Its maximum speed was 15 to 18 meters per second, and it traveled at an altitude never above 2,000 meters.

The use of the airplane seemed limited to operations during the day, especially for scouting and artillery-fire observation; its maximum speed did not exceed 30 meters per second, and its altitude not more than 2,500 meters.

I. Matériel.

The first consideration to be made was to realize the enormous field of fire in elevation and in direction.

(*a*) *Auto cannon—Regulation of fire from the burst.*—The 75-millimeter auto cannon had been studied and manufactured, before the war, with the essential characteristics of the matériel now in service; elevation from 0° to 70°, field of fire in azimuth 240°, placing in action on screw jacks, variable recoil brake, breech trunnions, counterbalancing springs for gun preponderance.

There was in existence at that time only one 2-gun section, simply as an experimental unit.

The pointing apparatus had been constructed with the idea of firing at balloons. The adopted method, called "Regulation of fire from the burst," presumed the possibility of making lateral and vertical adjustments of fire through the direct observation of the bursts, this being accomplished by adjusting the line of sight by the deviations between the burst and the target.

This method could be used against a fixed target, or target moving so slowly that the lateral and vertical deflection corrections at intervals of time corresponding to the time of flight of the projectile plus the lost time might be considered to be constants.

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(*b*) *Circular platform, model 1911.*—A fixed platform for the 75-millimeter field gun, model 1897, had been constructed before the war.

This platform, called circular platform, model 1911, allowed the vertical field of fire to be increased by raising the wheels of the carriage upon a circular band, having a pivot at its center, and the trail fixed to a bearing provided with a driving roller, resting in a groove on a concentric wooden circular band. The axle was fastened to the axis of the pivot by means of two stay rods, which prevented the carriage from jumping off the mount. The trail bearing was connected to the pivot by means of two more stays, in order to assist in steadying the mount fire.

The gun could be rotated through 360°. The maximum inclination of the gun, however, was only 30°. The maximum ordinate of the trajectory of 30° being approximately 1,800 meters, no target could be fired at when above this altitude.

This amount was soon found to be too limited. Trials were made to determine a means of increasing the maximum inclination by replacing the ordinary wheels of the 75-millimeter gun by larger ones, measuring 1.90 meters in diameter.

A maximum angle of inclination of 45° was thus obtained.

(*c*) *Improvised platform mounts.*—As early as the fall of 1914 a number of improvised platform mounts were constructed, both at the front and in the zone of the rear, owing to the lack of special anti-aircraft mounts.

All the devices were intended to increase the maximum elevation of the gun. This was accomplished either by raising the wheels on a revolving platform or in burying the trail.

Laying in azimuth was obtained, in the first case, by revolving the platform, and in the second instance by turning the gun around the pit, on a circular floor, upon which the buried trail rested. The maximum elevation was 48°.

In one case the gun carriage was raised on a platform, fixed by means of supports on a turntable with rollers, the base of which was set in concrete. The trail was borne by a slide moving over a circular track with horizontal butting. Laying in azimuth was made continuous by means of a mechanical control.

Another type of improvised mount, used at Dunkerque, with 75-millimeter casemate guns, consisted of a conical crinoline mount, having on top of it a vertical pivot. The axle, after removal of the wheels, was fastened to the pivot by means of stay rods.

The roller of the trail bearing ran on a circular track placed on the surface of the crinoline mount. This device allowed of a maximum angle of inclination of 60°.

Finally, a frame, turning in a pit made of concrete, allowed for fire at angles from 40° to 85°. This mount was tried at Verdun and Dunkerque in March, 1915. In this instance the mount rested on a central pivot step and its axletree arms on slides integral with the revolving frame.

In all these arrangements the 75-millimeter gun was provided with a special brake modified to take into account the additional load due to the vertical component of the recoiling mass.

II. Methods of Fire.

A large vertical and lateral field of fire is the primary condition in anti-aircraft artillery. But the problem is far from being solved simply upon realization of these conditions.

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Firing at high angles, even at a target supposedly "fixed," implies in the beginning the abandonment of the principle of the rigidity of the trajectory, and emphasizes the necessity of an elevation given solely in terms of the angle of site, and of the distance. On the other hand, the speed with which the target travels leads to the necessity of pointing the gun at a future position of the target, which should correspond to the fuze setter distance.

(*a*) Problem of superelevation abacus.—On the auto cannon the problem was resolved by the elevation dial.

With the first material, which was fitted only with a dial, graduated in mils, it was found necessary to improvise an apparatus allowing for the determination of this elevation in function of the fuze setter distance and of the angle of site.

A special chart was used, called "Superelevation abacus," upon which the elevations, corresponding to the ranges, and to the angle of site were read in mils. These elevations were transmitted verbally to the gunner in charge of elevation dial. This resulted in a considerable slowing down of the rate of fire.

(*b*) *Corrections due to the travel of the target—Graphic method.*—In order to determine the lateral and vertical corrections corresponding to the displacement of the target, a graphic method was first used.

These corrections depend on four variables—the angel of orientation of the target, its distance, speed, and altitude.

For a given altitude and speed, graphic diagrams for lateral and vertical deflections, established in function of orientation and distances, allowed the determination of corrections for every 15°. Distances were marked every 1,000 meters.

These diagrams were prepared for intervals of every 500 meters in altitude, and for speed intervals of 5 meters from 25 to 40 meters per second. Men regulating the lateral and vertical deflections read these corrections on these diagrams and applied them to the pointing apparatus.

The altitude and speed were assumed to be constant during the firing, thus allowing the use of a single set of curves.

Later these diagrams were printed in a book, each leaf of which corresponded to a certain altitude and speed, thus allowing change in speed and altitude during the fire.

(*c*) *Ranging—Optical telemeter—Barrages.*—At the beginning range finding was based only on the results given by Barr & Straud.

The accuracy of this apparatus, which depends essentially upon its adjustment and on the training of the operator, decreases, other things being equal, as the square of distances. With the 1-meter base instrument, range errors become very large—over 6,000 meters.

On the other hand, it is necessary to correct the range in order to take into account the travel of the target during the time of flight plus the dead time.

This correction often reaches 1,200 to 1,600 meters. It depends on the elements, speed, orientation, distance, and altitude.

Owing to the inaccuracy in the determination of the present distance, it was at first considered a folly to endeavor to determine the future position for each shot. It was considered proper to use salvos, called "barrages," when the ranges were short, in the case of a "coming" target, or *long* when the target was "going."

The corrections to be brought on the real distance for each "salvo" were read on diagrams similar to those of the lateral and vertical corrections, allowing for dead time, etc.

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Altitude telemeter.—About the middle of 1915 the introduction of altitude telemetry began the establishment of a rational method of fire.

The principle consists in deducing the range in function of the altitude and the angle of site. If the altitude is considered constant during the dead time of the fire, plus the time of flight, the future range could be determined from the knowledge of the actual altitude and the future angle of site. The latter is obtained from the actual site by adding the correction of site.

The altitude telemetry became effective only with the introduction of sufficiently accurate apparatus for measuring the altitude and the introduction of an automatic corrector for the determination of the future angle of site.

At first the altitude was found in an indirect way—by the horizontal distance obtained from the intersection of vertical planes passing through the target. The altitude telemeter gave only the present distance. The correction of range was made by means of graphic diagrams which, for a given altitude and speed, showed corrections in function of the two other variables, distance and orientation.

III. Organization.

Until 1918 auto-cannon sections were very few in number and widely scattered over both the zone of the front and rear. They operated as independent units.

At the front semifixed mounts consisted of field battery sections especially assigned to that duty.

Their personnel was not specialized. There was no liaison between themselves nor between them and aviation. There was no transmission of information nor of alarms; no established rules for the choice of the positions, this being left to the initiative of the local artillery commander; no regulation for the apportionment of units between the different sectors. Therefore the zones of action were much reduced, owing to dead angles. The tactical use of the arm was poorly defined.

The defense of the rear was almost nonexistent, except for the Paris defenses, which had been organized early in 1915. A network of observing and listening posts surrounded the city, having telephone connection with a general headquarters, in order to give warning of the approach of enemy aircraft. The first defensive organizations of the rear had no liaison either between themselves or with the organizations at the front.

EVOLUTION OF ANTI-AIRCRAFT ARTILLERY.

I. Matériel.

(*a*) *Increase of the number of auto cannon.*—With reference to the specialized automobile matériel, composed of the auto cannon, but few changes were made in the matériel.

The number was increased on the French front as quickly as the manufacturing of this matériel could suffice.

From 2 at the beginning of 1915 the number reached 20 on the 1st of January, 1916, 42 on the 1st of January, 1917, 70 on the 1st of January, 1918.

(*b*) *Trailers.*—A 75-millimeter mount of a trailer was designed. This could not be moved so easily and it had no horizontal dead angle. It was tested in 1917.

(*c*) *Platforms, model 1915.*—All improvised fixed and semifixed mounts were rapidly replaced by the platform mount, model 1915.

In this mount the wheels were removed from axle of the carriage, and the shields and wheel brakes were also removed. The gun rests in bearing plates,

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borne on a revolving frame; the trail is supported by a cable, which is fixed to the ring and winds on a winch borne on the frame. The latter is made of two triangular trusses placed vertically, the V planes of which make an angle of about 30°. The platform is provided with flooring, which is divided in its central part to allow space for the depression of the trail. The whole is placed over a circular pit, in the center of which a bearing is set to receive a central pivot fixed to the frame. The frame revolves around this pivot. At its extremity it is borne on rollers, which run on a circular track constructed on the edge of the pit.

The character of emplacement varies according to the nature of the defense, i. e., whether it be a well-fortified position or a temporary installation for the armies.

Elevation is about the axle of the gun and is accomplished by winding and unwinding the cable wound on the winch. The maximum elevation is 85°.

II. Methods of Fire—Superelevation Dial.

(*a*) The superelevation problem has been definitely solved for the platform; and for the auto cannon by use of abacus, which gives the superelevation in function of the fuze-setter distance and the angle of site. Mechanically this is accomplished by holding an index moving in site on the curve of the fuze-setter range announced.

(*b*) *Principal corrections of pointing—Goniograph—Sitogoniograph—Tachyscope—Orientation—Angle of approach—Telescope—Tachymetric method.*—The problem of determining the corrections due to the movement of the target has been solved by two principal methods: (1) Angle of approach method; (2) tachymetric method.

The angle of approach method was the first to be developed, since it does not require complicated measuring instruments.

It consists in calculating the vertical and lateral deflection corrections from the elements which define the motion of the target; speed, orientation, fuze setter, range, and altitude.

We have seen that the first phase of this method was the use of plotting boards used in conjunction with double entry tables of corrections calculated beforehand in function of the elements of fire. In place of these boards were soon substituted instruments which solved the formulæ for corrections.

About the middle of 1916 apparatus solving automatically these corrections were constructed; this apparatus, at first independent, was soon connected directly to the pointing apparatus.

The instruments were goniographs for lateral and the sitogoniographs for vertical deflection corrections. By means of these instruments the gun was automatically displaced by an amount equal to the proper corrections, by merely registering on the abacus the elements of the fire previously measured or estimated.

Progress was made in the determination of these elements.

The speed was first estimated by determining the type of airplane and then applying the speed characteristic of that type of plane.

The apparatus known as the tachyscope permitted the measuring of it from the displacement of the plane after its altitude was determined.

The angle of approach, i. e., the angle of the plane of path of the target with the vertical plane of sight, was estimated by the eye, relying on the various characteristics of each plane.

The angle of approach telescopes allowed this to be measured exactly, and be read on suitable abacus, either by bringing the cross hair coincident with the

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image of the fuselage of the airplane (telescope model 1916) or in the alignment of the symmetrical axes of the images, i. e., fuselage or the wings (telescope model 1917).

The tachymetric method, more scientific than the angle of approach method, consists in measuring the lateral and vertical angular velocities of the airplane, and in multiplying these values by the time of flight of the projectile.

It would give accurate results if it were possible to determine the mean angular speeds during the time of flight. But we have to be satisfied with angular speeds measured some time before the shot is fired. In multiplying these speeds by the time of flight we get approximate values of corrections. Various methods allow for correction of these approximate values in order to change them into exact values.

The tachymetric method requires accurate apparatus of delicate construction. Consequently, its problems were not definitely solved until 1917, although experimental apparatus had been tried out at the beginning of the war.

Actually two kinds of apparatus are in use. The one called corrector Brocq, A. A. (electromagnetic corrector), measures angular velocities by electrical means. These measurements are made at the battery commander's post by means of a double-sight element.

The multiplication of the angular velocities by the time of flight is also done electrically by means of a time rheostat. The corrections are read on properly graduated voltmeters. The time rheostat and voltmeters connected to the double-sight element by means of cables.

An element called pretelemeter can be placed beside the guns or at the battery commander's station.

In the mechanical instrument in use, called "Corrector R. A.," mechanical speedometers register the speed of the handwheels actuating the telescopes. The multiplication of the angular speed by the time of flight is effected by mechanisms between the handwheels and the speedometers. The apparatus includes an altitude telemeter. Telescopes, speedometers, and telemeters, with their mechanisms, are assembled as a unit in the same case. The deflection correction and fuze-setter range are telephoned to the guns.

(*c*) *Determination of the range—Altitude—Telemeter—Aiming wheel—Automatic corrector—Pretelemeter—Telemeter R. A.*—With the altitude telemeter the range is determined in function of altitude and angle of site.

The first telemeters gave only the actual distance to the target. Then, in order to change it into the future distance, tables were used.

To give automatically the correction of site to the altitude telemeter the first device used was the aiming wheel. It consists of a horizontal wheel of proper radius, its center set on a sliding support which was placed on the sighting alidade at a distance from the eye, varying indirectly as the speed. The observer sighted through the peep hole along the edge of the aiming wheel, keeping the fuselage of the plane normal to the circle. The alidade was thus directed at the future position and the future range was read on the apparatus as a function of the altitude.

When the telemeter with corrector was used the correction of site read from a table or on independent site. A goniograph was set on a graduation in mils over which moved a correction alidade.

Finally the telemeter, with automatic corrector (called a "limacon"), was designed. This instrument required only three elements in order to determine future fuze-setter range, speed, orientation and altitude, and angle of approach.

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A telemeter attachment has been fitted on the auto cannon. The alidade, graduated in altitude, registers directly the elevation of the gun, i. e., the future site. For slight errors, corresponding to the lost time, etc., a correction of altitude is made.

Regarding the electromagnetic tachymeter, corrector Brocq A. A., a telemeter with automatic corrector, based on an electrical principle and known as the pretelemeter, has been combined with this tachymeter.

Finally, the altitude telemeter of the mechanical tachymeter, corrector R. A., gives automatically the future fuze-setter distance.

All these instruments have the same fundamental principles, namely, future fuze-setter range is determined in function of altitude and future angle of site.

Determination of the altitude—Telemeter and altimeter.—The measuring of the altitude, which is of essential importance, was at first effected through horizontal telemetry in projecting the position of the airplane on horizontal planes.

The direct and accurate instrument for measuring altitude was a great improvement, and realized in 1916.

Base end stations several kilometers distant serve for this purpose. At these stations various instruments, known as direct altimeters, are used, viz, Puteaux altimeters, models 1916 and 1917, string altimeters, and horizontal distance telemeter, model 1917.

III. Secondary Corrections—Wind Ballistic Corrections.

The effects of the wind on the lateral and the vertical travel and the ballistic corrections are additional ones over those simply due to the motion of the target.

Wind corrections.—The direction and velocity of the variable winds found at different altitudes are measured. From them are obtained the direction and velocity of a constant fictitious wind, which for each altitude would give the same corrections as the actual variable winds measured.

Apparatus called "wind dials" have been constructed; they give at every moment, automatically, the lateral and vertical deflection corrections, which must be set on the pointing apparatus and the altitude telemeter for the site, in function of the registered elements and of the position of the plane of fire with respect to that of the wind.

Ballistic corrections.—The determination of these corrections necessitates the making of trial shots.

This experimental firing is effected on a fictitious target, determined by the intersection of the line of sight of the gun, with the planes of collimation of the altimetry stations. It involves the altitude, the corrector of the fuze setter, and the time of flight. It takes into account the wear of the gun, the characteristics of the lot of projectiles, as well as the atmospheric conditions of the day, i. e., temperature and pressure.

This procedure has replaced the old process of regulation of fire by observation of the bursts, which had been tried previously in different forms, the best of which consisted in finding the difference in altitude between the airplane and the bursts by means of observation grills. The telemeter marked this altitude correction. This regulation method was less accurate than the trial burst regulation, followed by a continuous altimetry. Observation regulation is now used only as a means of control, or when ballistic corrections have not been determined, or when the altimetry is defective.

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Projectiles.—In the beginning no time fuzes for the explosive shell were available. The use of this shell, adopted in 1916, for platforms, did not become general in anti-aircraft fire until the middle of the year 1917. It appears to have much greater effect, and to have more detrimental moral effect on the aviator, than shrapnel.

Shrapnel, with 30/55 fuze, capable of giving much longer ranges, is reserved for these greater distances.

Organization and use.—The development of the anti-aircraft artillery, the specialization of its methods, the need for liaison, has led to the creation of a special organization of this arm.

In each army a special commandant of the anti-aircraft artillery has been named. This commandant is placed under the orders of the commanding general of the artillery of the army. The front of each army and the rear of the occupied zone is divided into sectors. Each sector commanding officer is responsible for the defense of his territory, and serves as an intermediary between the firing units and the commandant of the anti-aircraft artillery, on the one hand, and between the firing units and the local defensive elements on the other. The firing units are connected by a special telephone system with each other and with the commanding officer of their sector. The latter keeps a note of alarms and information received, and telephones to the sectors concerned and to the battle planes. Each day he sends a report to the commandant of the anti-aircraft artillery on the firing of the day, consisting of a complete narrative with all information concerning presence of enemy aviation. He controls the supply of ammunition for his units and regulates their food supplies and the circulation of their wagons, barracks generally being grouped together.

All the anti-aircraft artillery batteries have day and night watches, whose business it is to report any signs of the presence of enemy airplanes.

The distribution of anti-aircraft artillery units among the sectors depends on the local activity, on the necessity which may exist of preventing aerial reconnaissance at any given point, and on the number and importance of the strategical centers to be defended.

These strategical centers, regulating stations, ammunition dumps, general headquarters, towns, and factories in the rear, are generally defended by fixed batteries. They are connected by telephone with the sectors on the front through the commandant of the anti-aircraft artillery. They occasionally have their own listening posts.

The zones to be swept on the front are those from which enemy airplanes can make observations, or through which they must pass to bombard or reconnoiter. As airplanes can see without crossing the line, it is important that the zones should extend as far as possible over the enemy positions. Use is made of auto cannon, trailers, and semifixed mounts. The advantage of the auto cannon is that they are more mobile, however, their visibility is also much greater. They generally occupy some central point from which they radiate in a given sector. It is also their business to accompany the general movement if any advance is made. The trailers and semifixed units are specially used to maintain a continuous barrage all along the front.

The intervals to be left between the batteries depend upon their zone of action. For any given gun the radius of action measured horizontally decreases with an increase of altitude. The zones are the projections of the circles of intersection of the volumes of revolution formed by the curves of security of trajectories with the planes of altitude, from which must be deducted the dead circle directly over the gun. Constant increase in the

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altitude of the airplanes has led to closer battery emplacements. Formerly they were at intervals of 10 kilometers, but now this is reduced to 4 kilometers, and, when it is desired to set up a double circle of defense, there is an average of one gun per kilometer.

PRESENT SITUATION.

Results obtained by the anti-aircraft artillery.—To appreciate the difficulty of anti-aircraft fire it suffices to consider that one is firing practically at a bird whose velocity is about 50 meters per second, i. e., one-sixth the average velocity of the projectile itself, in the case of the 75-millimeter field gun.

It is necessary to build up a reasonable hypothesis on the progress of the airplane during the preparation of fire, and the time of flight of the projectile.

On the other hand, the danger zone of the shell and the vulnerable surface of the airplane is small. Consequently the bringing down of the enemy aircraft is always an exceptional feat. The principal result to be hoped for by the anti-aircraft artillery fire is to prevent the airplanes from accomplishing their mission by obliging them to fly at increasing altitudes, and to continually change their direction. It is also possible to prevent their crossing certain regions.

At the present time the anti-aircraft artillery generally succeeds in keeping the airplanes beyond the limit of their range. Observation airplanes are obliged to fly out of range four or five kilometers behind the lines, and reconnoitering airplanes are obliged to increase continually the height at which they cross the lines. This height, which was 2,000 to 2,500 meters in 1915, rose to 4,000 in 1916 and to 5,000 and more in 1917.

Battle planes also fly very high, except when they wish to attack trenches or batteries with machine guns. Raids are almost exclusively carried on at night. The result is that three kinds of fire have become particularly important:

Fire against airplanes at a great range and a great height.

Fire against very speedy airplanes attacking our positions.

Fire at night against bombarding airplanes.

Each of these require special preparation and equipment.

Distant and high-flying airplanes.—To fire against distant and high-flying airplanes it is necessary to increase the range and diminish the time of flight of the shell. A temporary solution consisted in improving the range of the 75-millimeter gun. By changing the form of the explosive shell, its ballistic coefficient was improved. This gave the model 1917, D shell, whose range limits are considerably above those of the ordinary explosive shell: Maximum ordinate, 6,500 meters instead of 5,400; maximum horizontal range, 10,500 meters instead of 8,300.

In the case of shrapnel, its effectiveness has been improved at high altitudes by increasing the weight of the balls (20 grams instead of 12 grams). Toward the summit of the trajectory the remaining velocity of the shell is very low, and the velocity of the ball is practically reduced to that imparted to it by the bursting of the projectile. Therefore by improving the ballistic coefficient of the ball the effectiveness of its shell is also increased.

The question of increasing the range by the use of finned shells and muzzle recoil checks is being considered.

In the first case the fins keep the projectile to its trajectory without rotation of the shell, therefore it is possible to give the latter a shape which will reduce its resistance to a minimum.

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In the second case the power of the gun would be increased without any change in the carriage by causing the gases to escape through suitably shaped blades at the muzzle.

The model 1913, 105-millimeter field gun has been adapted to a platform which allows of firing in all directions and up to an angle of 85°, similar to that mentioned for the 75-millimeter. This reaches a maximum altitude of about 8 kilometers, and a maximum horizontal range of about 13 kilometers.

But the true solution of fire at high altitude, consists in the construction of powerful guns with high initial velocity. Two are now under consideration in France: a 90-millimeter gun, intended to be mounted on a platform and a 105-millimeter gun on a trailer, both from the firm of Schneider & Co. In the case of the latter an altitude of 10 kilometers and a horizontal range of 15 kilometers is anticipated.

If successful, the 75-millimeter gun will be used for defense at medium range. These powerful guns will be reserved for distant airplanes and captive balloons.

Low-flying speedy airplanes.—Against these airplanes use is made of machine guns mounted on a special tripod and fitted with a pointing apparatus based on the principle of the aiming wheel.

Actually, there has been a question of using a new arm called pom-pom; an automatic gun of small caliber and great muzzle velocity, firing explosive shells with supersensitive time fuzes, capable of bursting on coming into contact with any part of the airplane. Two guns of this kind, one of 37 and the other of 47 millimeters, are under consideration; but the shells must be provided with a supplementary safety time fuze to prevent accidents. This fuze has not yet been practically attained.

NIGHT FIRE—SEARCHLIGHTS—LISTENING APPARATUS.

Firing by sound.—When fighting against airplanes at night, searchlights are used to illuminate the objective. When it is able to find it and keep it in its field, firing can be conducted in the same manner as in daytime. Many sound detecting instruments have been made; the most recent one is the "Paraboloid." A surface in the shape of a paraboloid, movable in azimuth and site, focus the sound waves, when its axis is placed in their direction; they swing from one side of the focus to the other, when the axis of the instrument is turned. It is received by trumpets placed on either side of the focus and joined in pairs to the ears of two observers who adjust the instrument, the one for azimuth, the other for site. The range of the instrument which depends on its size, is about 8 kilometers for a 3-meter diameter paraboloid; that is to say, greater than that of the eye in slightly foggy weather. It is not sensitive to exterior sounds.

The search of the projectors was for a long time carried on by sweeping of zones varying with the opening of the shutter in the direction indicated by the sound. The working of the projector is electrically or mechanically controlled at a distance. This independent system has some chance of success against dirigibles, but is not considered practical for airplanes. This led to the study of mechanically controlled instruments depending on the listening instrument.

When the searchlight can not spot the airplane, because of fog, firing solely by sound must be relied upon. This fire, necessarily very uncertain, is based exclusively on the indications of the listening instrument.

The paraboloid has been combined with a route tracer which gives automatically, on a special graphic chart, established for azimuth and cotangent of site, the route of the airplane. From this graphic chart, by interpolation, approximately the azimuth and site suitable for each salvo is given. At the same time it also gives, approximately, the altitude at which the airplane is

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flying, assuming its velocity to be known by the measure of the time taken by the airplane to make any given displacement on the special graphic chart on which its route is traced.

This progress does not prevent night fire from being very inaccurate. All that can be hoped is an intimidating effect, and even this requires a great concentration of guns and intensity of fire.

Indirect fire—Telepointing.—At the front the guns must be hidden from the view of enemy observers and captive balloons. The result is that low-flying airplanes, although within range, can not be seen from the guns.

"Indirect fire" permits firing at these airplanes. It is only necessary that they should be visible from the battery commander's station.

This fire consists of calculating at the battery commander's station the future azimuth and range and sending this data to the gun, together with the altitude. All that the gun then requires for laying is an azimuth circle and an abacus giving the inclination of the gun that corresponds to the given range and altitude. If the battery commander's station is at some distance from the gun, the angles will not be the same at both emplacements. The differences, called "parallax corrections," may be too large to be neglected. They are corrected by instruments called "parallaxers," similar to the wind scales, and may even be combined with them. Thus with the model 1915 platform it has been possible to establish a means of indirect fire by assembling on the carriage abacus for inclination and by adding to the battery commander's station a parallax corrector and an azimuth scale with corrector.

The new fire-control apparatus, especially the corrector R. A., lend themselves easily to indirect fire. A special apparatus, based on an electrical process, the corrector V. C., is especially intended for indirect fire. It is at present used with the 75-millimeter trailer.

In order to obtain greater accuracy of aim the method of transmitting data by telephone is replaced by a process of distant laying called "telecommand." It consists in working the elevating and traversing mechanisms in such a way that a zero reading voltmeter always remains at 0. This voltmeter is connected between the two contacts of two similar rheostats installed—one at the battery commander's station the other at the gun—each of the contacts turning at the same rate as the planes of laying. This principle is that of the Wheatstone bridge.

Monostatic altimeter.—Another problem under discussion is that of the monostatic altimeter. Altimeters with a large base do not allow full advantage to be taken of the mobility of the auto cannon. They require a previously prepared emplacement and telephonic or electric communication. An optical instrument has been constructed based on the presumed knowledge of the dimensions of the objective. This solution is therefore necessarily subject to errors.

Other experiments are being carried out for the realization of an altimeter on a short base.

MISSION OF THE ANTI-AIRCRAFT ARTILLERY—RESULTS—STATISTICS OF AIRPLANES BROUGHT DOWN.

The above is a brief account of progress made in the matériel, methods, and organization of the anti-aircraft artillery.

In proportion as this progress increased, the conditions in which this arm is utilized became more difficult, on account of corresponding progress in aviation.

The velocity of the airplanes has increased from 30 to 60 meters per second, their altitude from 2,000 to over 5,000 meters. Experience has taught aviators to defend themselves against fire by continual changes in direction.

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The principle use of the anti-aircraft artillery has been to hinder aviators from carrying out their missions. The destruction of airplanes with the means actually at its disposal, is still a question of luck. Nevertheless, statistics show that there has been a constant increase in the number of machines destroyed; the following is a list of the number brought down by guns on the French front:

In 1915	2
In 1916	87
In 1917	124
In 1918 (first quarter)	42

During March, 1918, alone, 27 enemy airplanes were brought down on the French front by the anti-aircraft artillery, including 8 in the course of night raids. Two other airplanes were brought down by the defenses of Paris.

The importance of the anti-aircraft artillery is further shown by the amount of matériel brought into play. This matériel, on the French front alone, has varied, as shown below:

	Auto guns.	Platform guns.	Total.
End of 1915 (20 sections)	40	140	180
End of 1916 (42 sections)	84	200	284
End of 1917 (70 sections)	140	[1] 270	410

[1] 150 in first line.

The status of production of French anti-aircraft mounts, as given in courier communication dated October 24, 1918, is as follows:

75-millimeter auto-trailer type:	
Total number on order	450
Number now constructed	38
Additional number estimated completed by Jan. 1, 1919	42
Rate of anticipated delivery commencing Jan. 1, 1919 (per month)	30
75-millimeter auto-cannon type:	
Number in service	160
Number in fabrication	100
Estimated date of completion of these 100, Apr. 1, 1919.	
75-millimeter platform mount:	
Number completed	600
Number in construction	400
Estimated rate of delivery of these 400 (per month)	50
105-millimeter platform mount:	
Quantity on order	200
Number of order completed	[1] 150
Number in construction	50
Estimated rate of completion of these 50 mounts (per month)	25

105-millimeter trailer mount.—Two experimental units, including gun, mounts, and pointing apparatus, are under construction and will be given trial within the next six weeks. If these tests prove successful the French Government anticipate issuing an order for at least 150.

[1] Ninety of these 150 completed mounts are now equipped with 75-millimeter guns in lieu of the nonreceipt of a sufficient number of 105-millimeter cannon for which the platform was originally designed.

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STATUS OF THE APPLICATION OF THE MUZZLE-RECOIL CHECK (SYSTEM OSILLOT-BERY) TO 75-MILLIMETER GUNS FOR ANTI-AIRCRAFT MOUNTS.

Forty guns are now being constructed with muzzle-recoil check. These guns will be tried on both the trailer and platform mounts. Provided the tests are successful, the French Government intends to issue orders for the construction of 1,000 guns equipped with this device.

The chapter on anti-aircraft gunnery in the above is worthy of perusal and a few abstracts are repeated:

Common sense is the fruit of ancestral experience and anti-aircraft fire has only existed since the war.

Anti-aircraft fire will appear to one as a kind of game; but as a game in which chance singularly favors the good player.

Fifty meters a second, 3 kilometers in 1 minute, such is the speed of modern airplanes.

We realize the speed of express trains because we have seen them rush by us like a whirlwind in some small station where they scorn to stop. The airplane goes three times as fast and it thus gives us the same effect on a small scale as the passage of some astral body. We only believe it on the faith of learned astronomers. The airplane is a meteorolite, but it is a meteorolite which one sees from a great distance and which moves in a starless sky. Great distances, lack of reference points, these are like two curtains which mask the truth from us.

And, on the other hand, what have we at our disposal to reach the plane. Another meteorolite which is the projectile. * * *

We do not realize the speed of airplanes, we do not realize the slowness of the projectile. To believe it, one must have seen from a distance a shell tracing its way along its path with the movement of an idle king. Our 75 shells take 22 seconds to go 6 kilometers, 40 seconds to go 9.

Forty seconds in place of 180 for the airplane! It makes us ask ourselves whether the planes of to-morrow will go faster than the projectile.

The dissertation from which the above are quoted is written in somewhat different vein than applies to the majority of ordnance articles, but it excellently conveys an impression of the difficulties attendant upon the effective location by shell fire of a fast moving plane, and the sequence of the reasoning employed in arriving at some method of calculating this in accordance with a reasonable law of chance. The point is brought out that anti-aircraft fire is a continuous shifting of fire and that proper fire against airplanes is not adjusted, but is prepared, as there is no time for adjustment, in view of the rapidity of approach and passage of the target.

The following prognostication is made:

"We do not adjust, we prepare." This maxim which has been imposed upon us will sooner or later be applied to all forms of artillery.

The day will come when the field artillery will appreciate the importance of calculating in advance on the elements of fire and will be able without warning to concentrate by surprise on a given objective at any time of the day or night, the fire of any number of guns.

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In conclusion, the writer states:

The French anti-aircraft artillery employs instruments and methods which all the allied countries have copied.

They and all the Allies lack a good gun and a good shell. The time of flight ought to be divided by 4 and the dangerous volumes of burst multiplied by 10.

These are very difficult problems. * * * We can not yet definitely and positively prevent them (airplanes) from entering the zone of action.

* * * Aviation as an offensive arm will remain the principal arm.

Anti-aircraft artillery as a defensive arm will play the rôle that coast artillery plays to the squadrons of the high sea.

A minor rôle, perhaps, but one which will continue to increase with the progress of this arm of the service.

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Chapter II.

LIAISON WITH THE FRENCH AND BRITISH.

The previous chapter describes the development and its sequence in the experience of the French. In a separate report dated January 1, 1919, from the same American Expeditionary Force sources, a tribute is paid to the thoroughness of the French in their investigations and to the assistance rendered by them to the American forces. Their manufacturing activities were centered at Puteaux Arsenal, and they exhibited a readiness at all times to cooperate. Information concerning the organization and equipment of the anti-aircraft defenses of Paris and the interior of France was obtained through the courtesy of Gen. Ranaud and his staff of officers.

Information concerning the London anti-aircraft defense, which includes all operations from the coast inland, was obtained through the courtesy of Maj. Gen. Ashmore, of the British Army, and his staff.

What might be termed laboratory research was, in the case of both nations, carried on on a high plane, but while the French battery commanders were for the greater part men of engineering experience, the British officers were drawn without reservation from all walks of life, and very few of them were of the engineering profession. The French were therefore in a better position to cope with the mathematical reasoning of anti-aircraft fire-control problems, and this will largely explain the better results obtained by the French.

The anti-aircraft experiment section of the munitions invention department of London, England, was of great assistance in establishing our procedure, and while differing at first, the British eventually arrived at the same theoretical reasoning of anti-aircraft methods as had been established by the French.

Previous to the beginning of this war the science of anti-aircraft gunnery was unknown, but through the cooperation of British, French, and American scientists and engineers, this is now progressing on well-established principles.

As between the products of the British and French schools of design, the British have not attracted the same attention as the French, but their new 3.6-inch caterpillar mount, anti-aircraft matériel, exhibits many good features.

As a result of many conferences it was the consensus of opinion that corrector V. C. in its modified form offered the best solution

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of central post fire-control apparatus for anti-aircraft guns. This is the invention of Mr. Van Cauwenberghe and involves a system for arriving at and transmitting the information necessary to the direction of fire in accordance with advanced principles.

Concerning the design and construction of the corrector V. C., it represents by far the most complicated electrical device of its kind yet undertaken. The working parts are numerous and most of them very light. It is a device necessitating most expert workmanship and adjustment. Having these characteristics, it was thought that trouble might be experienced with the apparatus in the field. Concerning this point it is in order to state that the French had the first model apparatus along their front almost continuously for the last eight months. No troubles whatsoever have been experienced with any of the working parts. It has been given little or no attention when being transported from point to point behind the line. Practice has therefore proved that mechanically it has been able to withstand the average conditions of field operation.

As this instrument is for use in indirect-fire control, it is particularly applicable to the more powerful types of guns, such as our 4.7-inch. The British have recently placed an order for one instrument and the United States Government has also purchased one.

With reference to the transmission of deflection settings for the guns telephones have proved very successful, but with the direct electrical method, the voltmeters placed either on the gun carriages or adjacent thereto, permit the reading of the corrections without loss of time. There is, however, the disadvantage of a more elaborate wiring system and the opportunity for error through lack of the greatest care in making perfect electrical connections and through possible differences in temperature effects, due, for instance, to one connecting cable passing through water.

Wireless telephony can be employed very advantageously for anti-aircraft service by utilizing the lower wave lengths in order not to interfere with airplane communication.

In connection with ammunition, a combined effect of spin, pressure, and self-heating of fuzes, had been deduced and a conference was held on November 7, 1918, in the University of London, for the purpose of discussing the general problems relating to this effect. A unique device had been constructed for spinning fuzes under every condition comparable with those encountered when a projectile is actually fired from a gun. These provisions included methods for producing rotating speed, air pressure above and below normal atmospheric pressure, and temperature changes for the purpose of studying the self-heating of the fuze due to the heat generated in burning the powder time train. The effects of air pressure and of self-heating will be readily appreciated, but the variation due to spin might escape one at first glance. The explanation seems to be that different fuze train compositions leave different quantities or

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texture of slag in the process of combustion, and that the mechanical disintegration of the burning surfaces, which takes place as a result of the action of this residue under high centrifugal force, differs accordingly and affects the rate of burning, sometimes causing complete stoppage.

The study of the British concerning the anti-aircraft projectile fuze question deserves considerable merit and attention. We should profit by their experiances and continue work along the same line if we anticipate using ring type powder train fuzes for our anti-aircraft ammunition.

On November 8, 1918, the first of the British 3.6-inch anti-aircraft caterpillar trailer mounts, which had just been completed, were inspected at Woolwich Arsenal. A brief résumé of the observed points follows:

GUNS.

Bore	3.6-inch.
Muzzle velocity	Design for a maximum of 2,500 feet per second.
Length of tube	44 calibers.
Recoil	Up to 50° elevation of gun, 24 inches constant; above elevation of 50°, variable from 24 inches to 33 inches.
Breech	Sliding block.
Trunnions	Located close to breech.
Weight of shell only	Approximately 25 pounds.
Weight of ammunition complete per round	Approximately 37 pounds.
Angles of elevation	0 to 80°.
Time to depress gun from 80° to 0° on slow gear	13 seconds.
Time to elevate gun from 0° to 80° on low gear	20 seconds.

CATERPILLAR CARRIAGE.

Weight of unit complete, including gun and its counterweight of 2 tons	17 tons.
Width of caterpillar tread	24 inches.
Bearing length of tread	About 7 feet.
Time to traverse gun through 360° on high-speed gear train	52 seconds.
Time to traverse gun through 360° on low-speed gear train	2 minutes.
Stabilizers	4 in number, located 1 at each corner.
Leveling	2 seats, of spirit levels provided on caterpillars.
Brakes	Not yet provided on caterpillars.

POINTING APPARATUS.

Practically speaking, the method of pointing the gun is quite comparable to that of the French auto-cannon and trailer type. Graphic means of working out equations giving the actual lateral and vertical deflection corrections as

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well as superelevation is provided. A wind dial which will be augmented by a parallax indicator is placed on the mount. Every means for operating the gun for direct or indirect fire is provided. The universal joint is employed in order to compensate for what is known as the complementary term correction of our equations. Provision for setting corrections in either horizontal plane or the plane of sight is incorporated.

GENERAL.

Every attention has been given in the design to provide ample working space for the gun crew. This is of extreme importance. The ease with which the gun carriage can be traversed and the gun elevated is notable. The matériel complete is worthy of minute study by us before attempting to lay down a definite design of mount having similar characteristics.

The London anti-aircraft defenses were inspected on November 9, 1918, and particular attention was paid to the maneuver of the guns, searchlights, and sound-locating apparatus. Three-inch platform mounts constituted the greater part of the defense.

The London central controlling station commands all anti-aircraft means of defense throughout England. It had just been completed and had never been tried under conditions of actual attack.

Wireless telephony plays an extremely important rôle in communicating from the headquarters in London to different fixed points throughout England as well as squadrons of airplanes, that constitute a part of the night defenses.

If we anticipate defending areas in the United States against aircraft raids it would be well to thoroughly study the London aircraft methods before undertaking our work. They are so far in advance of the methods employed by the French in defending the Paris region that the French system could be well eliminated from study.

In connection with the previous quotation, it may be well to refer to the report, dated June 12, 1918, of the Research Information Committee, subject, "German Air Raids Against Paris: Tactics of Attack and Defense."[1] This report indicates the general location of anti-aircraft batteries and searchlights and states that the raiding squadrons always approached along the route of some of the railways or along the river, as they frequently got lost if attempting an approach across country. Listening posts were stationed between the front and Paris, and, on detection by these of an approaching enemy airplane, the news was telephoned to Paris and the anti-aircraft batteries in line with the course of approach were notified to send up a protective barrage, The density of this barrage may be judged from the fact that there are from 6 to 10 cannon in each battery and each cannon may have as many as eight unexploded shells in the air at one time. It is stated that, although planes were seldom brought down, 90 per cent were prevented from directly reaching their objective. The planes either turned back or turned aside in an endeavor to reach

[1] Tech. Staff File 452/27.6.

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Paris by another route. In another part of the report it is stated that the number of direct hits was very small, amounting to approximately one in 30,000 shots. Friendly airplanes also had a place in the protective plan, but not so much for the actual defense of the city from night attack as to harass the enemy on his return. Numerous small balloons were also sent up at night and anchored along the large boulevards and parks of the city. The effective part of this balloon equipment was the wire cables by which the balloons were anchored, since the impact of an airplane which might have penetrated the outer barrage against one of these cables would probably wreck the airplane. The approach of the majority of the German airplanes was detected sufficiently in advance to give warning, but an isolated instance of bombing without warning was probably the result of a flight at great altitude and a later coasting down of the plane on Paris without motor noise.

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Chapter III.

FIRE CONTROL AND AMMUNITION.

While this is a history of anti-aircraft guns, and it is not the intention to go into detail regarding the fire-control equipment for directing the fire of these guns or of the ammunition employed with them, the entire development is so new and the three elements are so bound together in the development that it has been necessary to devote some space to the fire-control equipment, and a brief reference will also be made to the ammunition.

As to the terms employed in connection with the fire control, many of them are similar to those employed with field artillery practice, and "Angle of approach," "Angle of superelevation," and "Angle of quadrant elevation" are largely self-explanatory.

The fuze-setter range is a fictitious range expressed in meters at which the fuze must be set to produce a burst at a given point in space.

The engine speed is the true speed of the airplane in still air.

The goniograph is an instrument for determining the lateral deflection and applying it to the gun when using the angle of approach method.

A sitogoniograph is an instrument for determining the vertical deflection and applying it to the gun when using the angle of approach method.

The goniotachymeter is an instrument for determining the lateral deflection and applying it to the gun when using the tachymetric method.

A sitogoniotachymeter is an instrument for determining vertical deflection and applying it to the gun when using the tachymetric method.

A mil is a unit for measuring angles and is 1/6400 of a circle.

A grad is also a unit for measuring angles and is 1/400 of a circle: 90°=100 grads, or 1,600 mils.

An altimeter is an instrument for obtaining, automatically, the altitude of the target.

The telemeter is an instrument for determining the fuze-setter range.

A range drum is an instrument graduated in fuze-setter ranges by means of which the superelevation is given to the gun.

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The principal lateral and vertical deflections are the deflections to correct for the travel of the target during the time of flight of the projectile.

The secondary lateral deflection is the lateral deflection to correct for windage and for drift due to the rifling of the gun.

The secondary vertical deflection is the vertical deflection to correct for windage.

The first, second, and third positions considered in anti-aircraft gunnery are the position of the target at the instant of observation, at the instant of departure of the projectile, and at the instant of burst.

The lost time represents the interval between observation and the departure of the projectile.

The tachymetric method is the method of determining the vertical and lateral deflection angles, which must be set off to allow for the travel of the target during the time of flight, by measuring the angular speeds and multiplying by the time of flight.

A treatise on "The Tachymetric Method of Fire Control Against Aircraft," as of date of January 11, 1919, may be found in the Technical Staff Library.

The V. C. central station apparatus for anti-aircraft service, known as "Corrector V. C.," is the most elaborate and most highly developed example of fire-control equipment. For detailed description, see "Corrector V. C. for Anti-aircraft Service," prepared by Capt. R. L. Goetzenberger, Ordnance Department, in collaboration with Mr. Van Cauwenberghe, the inventor of the apparatus, from which the following information is obtained:

Its object is to avoid error in indicating the target by concentrating the various sighting appliances into one; to simplify the work of the gunners and that of the operators of apparatus by rendering operation automatic (the altitude being supplied, the apparatus directly indicates the azimuth, the inclination, and the fuze punch distance); to enable the principal operator to remain at some distance from the gun and thus avoid the noise in its immediate vicinity; to reduce to a minimum the exposure of men and equipment to enemy observation and fire (with the use of this system it is not necessary for the gunners to see the target, and they and their guns may therefore be concealed); to command several guns simultaneously by supplying them with identical data for firing and to obtain therefrom a rigorously comparable fire; to concentrate in the fire commander all of the corrections in ranging and thus avoid errors arising from the personal factor of various operators, who, with this system, must obey the indications given by the apparatus.

The control apparatus is divided into two parts—the sighting apparatus and the fire-control apparatus. The sighting apparatus

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alone is exposed to enemy fire, as the central station instrument may be placed in a shelter.

The sighting apparatus consists of two right-angled telescopes, mounted in the same casing and having their optical axis strictly parallel and driven for elevation and direction by two handwheels. This instrument is set on a tripod in some commanding position and is electrically connected to the central station instrument.

The central station instrument consists of a casing, inclosing various mechanisms and exhibiting on its exterior surface various gauge and dial readings. This instrument is set up on a tripod in some quiet and protected position, from which direct electrical and telephone and microphone connections are read with several guns. Around this instrument special stools are located for the convenience of five operators, each one of whom devotes himself to a separate gauge or dial reading on the instrument.

At each gun there are four gunners—direction, inclination, fuze punch, and corrections—each connected by telephone or direct electrical instruments with the central station.

When the approach of an enemy plane is observed two men man the two telescopes of the sighting instrument and operate the handwheels until the target is brought into the field of the telescope, and it is there maintained by the use of handwheels. The electrical connections synchronize the movements thus obtained with the apparatus in the central station instrument, and the various corrections are applied, such as those having to do with windage and atmospheric conditions, and the corrected information continuously transmitted to the gun positions. The battery commander then orders "Open fire" or "Cease fire," as his judgment dictates.

This, in brief, conveys a general impression of the most elaborate and ingenious fire-control system which has yet been devised. In view of the very important part which aircraft played in the present war and the proof which has been exhibited of the possibility of largely frustrating enemy aircraft attack by means of anti-aircraft guns, it behooves the American anti-aircraft gunner to thoroughly familiarize himself with this device and the further modifications which may be looked for.

It will also be noted that a clear conception of the similarity of other protective apparatus in the hands of enemy anti-aircraft gunners must be of great service to friendly aircraft operators in devising methods for their own protection and to circumvent the enemy anti-aircraft methods in vogue.

In connection with the fire control there may also be mentioned the searchlight and the sound-detecting instruments and wireless telephony, which have been mentioned on pages 20, 21, and 28.

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As to the ammunition for anti-aircraft guns, this is in a condition from which much development may still be expected. Indications of the direction of such development may be noted on pages 8, 19, 20, and 23.

For the artillery it includes shrapnel, high-explosive tracer, incendiary, and illuminating. High explosive has largely succeeded shrapnel, and with the use of the latter the tendency is toward a larger ball. The American policy of design is to combine the tracer and the incendiary shell and to fit it with a time fuze, whereby the elements are conserved and the earlier part of the trajectory is not disclosed. The present illuminating shell of American design will probably be supplemented with a parachute attachment to maintain the illumination at an elevation for a longer period. The "pom-pom" type of projectile, with its impact fuze of sufficient sensitiveness to be detonated on impact with balloon cloth, will probably have a safety-fuze element to insure explosion before reaching the ground, consisting of a tracer attachment, set in the base, which would cause the explosion of the projectile when nearly consumed.

The machine-gun anti-aircraft ammunition consists of the service bullet and the armor-piercing bullet, which are solid; the tracer bullet and the incendiary bullet, although the two latter may be combined; as well as an armor-piercing bullet and tracing feature. Some experimenting has also been carried on in connection with a spotlight bullet, which shows light only on impact. Incendiary bullets shot from airplanes were most effective in setting fire to Zeppelins.

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Chapter IV.

ANTI-AIRCRAFT ARTILLERY.

The anti-aircraft artillery utilized at the end of the war by the French, British, and Americans is tabulated below:

FRENCH.

Carriage.	Gun.
Semifixed (platform)	75-mm. field type.
Auto cannon (truck mount)	75-mm. field type.
Remorque (trailer)	75-mm. field type.
Semifixed (platform)	105-mm. field type.

BRITISH.

Pedestal (platform)	Q. F. 3-inch 20 cwt.
Motor lorry	Q. F. 13-pdr. 9 cwt.

UNITED STATES.

Improvised mounts (semifixed)	75-mm. field type.
Auto-truck mount	75-mm. field type.

Reference has been made to the French and British equipment in Chapters I and II.

Some 50 of the above-noted improvised mounts were manufactured in the United States and shipped to France (shipments beginning in December, 1917, and continuing until the summer of 1918), to be there equipped with French model 75-millimeter field gun, with Puteaux recuperators, and to be used as anti-aircraft equipment. Changes in these mounts were decided upon in France after their arrival. The American improvised mount consists of a fabricated steel frame set on an annular ring, which was provided with an internal gear for rotating the mount through an azimuth of 360°. To the framework were attached platforms for the convenience of the gunners. It was the plan to carry the mount and gun on auto trailers or other means of transportation to a determined position and there set them up in a rather elaborately prepared pit surrounded by wood piling, which required about two weeks' time for the preparation and mounting of the gun.

The American truck mounts consisted of White automobile trucks, on which were placed, with special hydrospring recoil mounts, American model 1916 field guns.

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It may be mentioned that the Italians also had a 75-millimeter improvised anti-aircraft mount and a 102-millimeter anti-aircraft truck mount. The Italian improvised mounts consisted of field guns on their carriages, arranged for high elevation by blocking up the wheels, and these carriages were sometimes set on pivots. They also employed guns set on timber mountings and arranged with a crude recoil mechanism, consisting of weights, attached to the gun mounting by means of ropes, which ropes passed over rollers. Their auto-truck mounts were arranged for all-around fire.

At the time of the armistice there were in various stages of design or manufacture the following anti-aircraft equipment:

FRENCH.

Carriage.	Gun.
Trailer	Bore, 105 mm.; M. V., approximately 735 m/sec.
Trailer (experimental)	Bore, 90 mm.; M. V., approximately 750 m/sec.

BRITISH.

Caterpillar trailer	Bore, 3.6-inch; M. V., 2,200 ft.-sec.

UNITED STATES.

Trailer mounts	3-inch, model 1918.
Caterpillar mounts (experimental)	4.7-inch.

In the United States 3-inch seacoast anti-aircraft guns, model 1917, both for fixed position and mounted on automobile trucks, were manufactured and available and were placed at the disposal of the American Expeditionary Forces, but were declined.

Of the equipment, not used but under design or manufacture, the French 105-millimeter trailer mount is referred to an page 22 and the British 3.6-inch caterpillar trailer is described on page 27.

The American 3-inch model 1918 anti-aircraft trailer mount was the weapon on which the United States anti-aircraft artillery program was centered, consisting of a specially designed 3-inch anti-aircraft gun, with a specially designed hydrospring recoil mechanism, mounted on a rubber-tired trailer provided with outriggers.

One thousand one hundred and two guns and 612 trailers and mounts were on order in the United States, and the manufacture of this matériel was well along. The pilot equipment had been proof-fired, but difficulty had been experienced in satisfactorily adjusting the recoil. This was satisfactorily adjusted and arrangements made to assemble in quantity at the time the armistice was signed.

The 4.7-inch caterpillar mount was an experimental equipment, and will be dealt with in detail in the chapter on the participation of the United States.

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The 3-inch seacoast type of anti-aircraft gun is a powerful weapon, firing a 15-pound projectile, with a muzzle velocity of 2,600 feet per second and having a maximum horizontal range of 16,500 yards, a maximum vertical range of about 8,000 yards, and a maximum elevation of 85°. One hundred and sixty of these equipments were on order and 90 had been completed by November 1, 1918. More could have been completed by that date had they been desired by the American Expeditionary Forces. Five of these weapons had been mounted on heavy motor trucks and part of the balance had been distributed for defenses other than in France.

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CHAPTER V.

ANTI-AIRCRAFT MACHINE GUNS.

In the previous pages there has been developed a general narrative relating to the developed theory, or the theory in the course of development, in connection with anti-aircraft-gun fire and the matériel which has thus far been designed. Experience has determined certain general requirements, and has emphasized the desirability of ready mobile equipment. The several altitudes have been mentioned at which aircraft are encountered and a limited experience has indicated a surprisingly large amount of low-angle fire with anti-aircraft artillery pieces, although much barrage and selective firing has doubtless been done at high angle.

As the anti-aircraft artillery units in service have not been numerous, this latter experience will emphasize the possible effectiveness of a large number of short-range weapons, widely distributed, although it is possible that considerable of the low-angle anti-aircraft artillery fire was directed toward aircraft in positions of considerable distance behind the enemy front line. Irrespective of this, there is other evidence of low altitude enemy flying over our lines. While the earlier anti-aircraft artillery fire was directed by observation of the burst, it was seen that this eventually gave way to direction of the fire by carefully deduced principles. Nevertheless, the anti-aircraft artillery theory lays but little stress upon the possibility of incurring damage through a direct hit by the projectile which is fired from the gun as it is considered that the possibility of such hit is too remote. The artillery practice is, therefore, to so direct the projectile that it will explode at a more or less predetermined position and cause damage either by the fragmentation of the projectile, which covers a very much larger area than the intact projectile, or through the concussion caused by the exploding projectile and whose effects would also be felt through a considerable atmospheric sphere. It will be seen, therefore, that apart from the artillery and the field of operations proposed for the "pom-poms," there is a distinct field for an anti-aircraft gun whose principle of fire is entirely different from that involved for the artillery. This principle involves projectile impact and rapid fire, with the obtained trajectory made visible in season to permit of corrections in aiming by the individual gun pointer, while the target is still in range.

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At low altitudes the machine gun, fired from the ground, provides the medium through which this principle may be applied, and for high altitudes the principle may be applied in the same manner by mounting machine guns on friendly airplanes. In this history we are not, however, directly concerned with aircraft armament.

The machine gun, being light and comparatively low in cost, as compared with artillery, may be readily and rapidly transported, and large numbers supplied to personnel distributed over a wide area. Likewise the ammunition, being light in weight and low in cost, may be supplied in larger quantities and expended more freely than the artillery projectiles. Machine-gun fire from the ground has been much more effective than is generally appreciated in actually bringing down enemy aircraft, and there is no way of determining the additional damage which has been inflicted upon enemy aircraft without actually bringing the plane down within the view of friendly observers.

The increasing appreciation of the effectiveness of anti-aircraft machine guns is illustrated by the plans which were being made for the much wider distribution of weapons for this purpose among the different branches of the service; to be manned continuously as anti-aircraft equipment or to be employed as supplemental protection and manned as anti-aircraft equipment under emergency conditions.

The needed equipment was divided into the guns themselves, improvised or especially designed mounts, means for transport, sighting devices, and the establishment of routine methods for the employment of matériel.

The machine guns in use by infantry included the Colt, Hotchkiss, Lewis, Marlin, Vickers, heavy and light Browning, Chauchat, and St. Etienne.

The anti-aircraft machine-gun plans and schedules arranged for the American troops during the present war were centered on the Hotchkiss machine gun for a number of reasons. More of these were available than of any other type, as they were being withdrawn from the infantry units as the Brownings became available, and the total supply was quite sufficient to cover the anti-aircraft requirements, as planned. These Hotchkiss guns were chambered for 8-millimeter French ammunition, which has a more sustained trajectory than the United States .30 caliber and consequently permitted effective fire at a greater range and altitude than could be accomplished with a .30-caliber gun. It was the only available gun to which an existing system of fire control could be applied, due to the fact that it was the only one for which a satisfactory anti-aircraft sight had already been designed and was procurable, and 8-millimeter tracer ammunition was procurable to at least a small extent, while .30 caliber tracer ammunition would not be procurable until

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the fall of 1918. Instructors in anti-aircraft fire had been trained to French equipment. The gun was strip fed and, hence, no feeding difficulties were encountered; and they were encountered with belt feed, unless ammunition box racks or supporting brackets were provided to insure the movement of the belt with the gun. In view of the heavy demands made upon manufacturing facilities in the United States to supply the Browning to infantry and air service, it did not seem desirable to call for the development of a separate type of Browning for anti-aircraft work, with the fairly satisfactory Hotchkiss available.

The main difficulty encountered in furnishing an adequate supply of anti-aircraft machine guns and attendant accessories was due to the constant increase in the authorized allowances of guns for this purpose, as their effectiveness became apparent. In April, 1918, they were authorized for issue to heavy and railway artillery units, balloon and searchlight companies, and in May, 1918, provision of 500 was called for for the protection of railheads, dumps, etc., and in July, 1918, they were authorized for issue to 240-millimeter trench mortar batteries and later the authorization for their use with railway artillery was increased from one to four per battery.

It was expected that the French would be able to supply the Hotchkiss gun requirements for both ground organizations and anti-aircraft service. These expectations were upset by the increased troop movements and by delayed deliveries. Delayed deliveries from the United States of Brownings for infantry units also delayed the availability of displaced Hotchkiss guns. This replacement had been expected to start October 1, 1918. When it became apparent that the situation was critical, efforts were made to secure converted Marlins from the United States until the Hotchkiss guns should become available. It was also considered that the Marlins might prove superior to the Hotchkiss, on account of the Marlins' greater rapidity of fire. Five hundred of these Marlins were secured for shipment to France in September, 1918. Certain alterations in the Marlins were necessary, and it had been expected that these alterations would be made in the United States or that the necessary parts would be supplied. This did not prove to be the case, and designs were made in France for the necessary adaptations, but it was not possible to have the alterations made in season to permit of the converted Marlins being available by the time of the signing of the armistice. The situation was relieved by the cession of the French of 500 Hotchkiss guns in September. The demands for machine guns for organizations in line were met at all times, but there were some delays in providing guns for training purposes.

The Browning automatic rifle was also considered for anti-aircraft purposes in connection with anti-aircraft artillery battalions, and was

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later tried out in the combination of two guns mounted in parallel. The following comment pertaining to them was made in a report from the director of the Army Anti-aircraft School:

These rifles and mounts function perfectly at all times. The rate of fire was extremely high and the resulting cone makes it highly probable that an enemy plane operating within 1,000 meters would be hit. These rifles, so mounted, would probably only be used for the defense of fixed posts, etc., as they are rather heavy and cumbersome to be taken on the advance. If used for fixed defense, a more accurate sight than the trench type would be necessary. In fact, a slight modification of the infantry corrector would make its use entirely practicable.

All available Browning automatic rifles were, however, needed by the line troops.

A combination of two Marlin guns, one above the other, and supplied with a common stock and a trigger, worked out especially well on account of its high-firing power, but its unwieldiness precluded its use for other than fixed defense work.

It is understood that experiments were also undertaken in the United States with combinations of four or six guns operated from one mount and by a common trigger, with the particular object of establishing machine-gun barrages for the defense of balloons (two guns leading and two guns lagging).

The best success obtained during the war in the use of machine guns against aeroplanes was obtained by the First Anti-aircraft Machine Gun Battalion in the St. Mihiel drive and subsequent operations, and by the Second Anti-aircraft Battalion which went through the Argonne offensive. Some of the balloon companies were also successful in driving away attacking planes.

From a purely engineering standpoint the accessories to anti-aircraft fire have probably received more consideration than the guns themselves.

The British appear to be entitled to the primary credit for employing machine guns against enemy airplanes. They started with improvised mounts, the most notable of which was the combination of the Vickers gun lashed to the wheel of a wagon. However, their main employment was of their Mark IV tripod, with the gun reversed, arranged with sand bag or other blocking or small trenches, to permit of the gunner getting directly behind his piece.

In 1917 the French initiated the development of special mounts, and this was followed by American development and manufacture, although both had in the meantime employed improvised mounts. The special mounts more particularly took the direction of tripods, light in weight, stable, permitting of all-around fire, and of an arrangement to permit of convenient operation of the gun.

The Cygnet mount, manufactured in the United States, was reported by the American Expeditionary Forces as not suitable for the work of the Anti-aircraft Machine Gun Battalion, as it was too cumbersome and its elevating mechanism was too slow. It appeared

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more particularly applicable for aerial barrage, and was judged suitable for the spare gun assigned to searchlight units and for balloon-defense units.

The necessity was recognized for some form of specialized sights or fire control, and different types were worked out by the French and British, with a view to providing adjustments for the several variables. As a rule the adjustments were too complicated to be handled by the general personnel, and the tendency was then toward simplicity. The outcome was two main types of sights; one for the forward area, which was based on an average of the varying conditions for the flight of the target; and the other, which was known as the dump sight and which was more complicated, and usually required one man besides the gunner for its operation.

The first sight which came to the attention of American Expeditionary Forces was the French P. B. corrector, but the infantry corrector sight was the sight used by American Expeditionary Forces. Early in 1918 the British forward area or trench sight was brought to the attention of the Ordnance Department and was used as a basis for the development of a standard sight for the Browning automatic rifle and Browning machine gun and these were also arranged, by the aid of different brackets, for the Vickers, Marlin, Lewis, and Hotchkiss guns.

The Peycru sight, which is thought to be the best all around dump sight, is a development of the infantry corrector sight, but none were received by American Expeditionary Forces.

The use of tracer ammunition as an aid to the sighting or fire control is thought to be necessary, and it has gradually become the practice to depend upon tracer ammunition as a fire corrector, after the cone of fire has been brought into the neighborhood of the target.

High-power telescopes are of the greatest importance, to enable the gunner to distinguish between friendly and hostile planes. This determination is frequently very difficult in the early morning hours, at which time a great deal of the fighting takes place.

Both the Chauchat and Browning automatic rifles were used by the infantry for firing at airplanes, but the former was unsatisfactory on account of its wide dispersion above 200 or 300 yards, and its heavy weight and heavy recoil. The Browning rifles proved very satisfactory and have been suggested as an anti-aircraft weapon for cavalry.

During the early stages of the war, it was contemplated that anti-aircraft machine-gun battalions would operate at a considerable distance in the rear of the front lines, for the protection of communications, headquarters and ammunition dumps; their function thus being purely for anti-aircraft fire. During the St. Mihiel attack the anti-aircraft battalions engaged were sent well toward the front for the purpose of protecting the infantry from low-flying planes. This

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change in tactics emphasized the importance of the ready portability of guns, ammunition, etc., and that the guns must be able to operate against enemy ground personnel, both for the protection of the anti-aircraft gunners and to add their fire to that of the infantry at crucial moments.

The consensus of opinion is that machine guns now in use are practically noneffective against aircraft flying at an altitude above 800 or 1,000 meters, and that their really effective fire is limited to about 600 meters. The present anti-aircraft artillery fire is largely ineffective against planes flying below 2,500 meters altitude and at ranges under 3,500 meters on account of the difficulty in maneuvering the guns to provide for the rapid changes which such positions usually involve and on account of the wide variation in time of the action of the fuzes at these short intervals and the danger to friendly personnel.

There is need, therefore, for an anti-aircraft machine gun to cover this zone between 800 meters and 2,500 meters altitude and under 3,500 meters range, and it is considered that the ideal gun for this work would be one between the .50 and .75 caliber, air cooled, fitted with a stock and pistol grip in positions similar to those held by the same pieces on the Lewis gun; and with an ammunition-box bracket fitted to the gun itself and so arranged as to distribute the weight of the ammunition equally on both sides of the barrel. The muzzle velocity of this gun should be as high as possible and preferably in the neighborhood of 3,000 feet per second; the ammunition to be supplied in expendable belts and boxes containing approximately 100 rounds each. It has been suggested that enemy anti-tank ammunition, properly adapted, represents the type of ammunition which would be most effective. The rate of fire should be between 500 and 700 rounds per minute.

Water-cooled guns for anti-aircraft work are subject to the objections of additional weight; the slopping of the water in the water jacket tending to carry the muzzle of the gun past its mark when moved rapidly to follow the erratic course of the low-flying plane; the drip of water upon the breech belts when firing at a high angle and the danger of freezing of the water in cold weather.

The air-cooled gun is superior in connection with all of the above points, and for anti-aircraft work, the gun is not called upon to deliver sustained fire, with its consequent heating effect.

It has been suggested that this larger caliber gun, when not needed for anti-aircraft work, might be employed to advantage against enemy tanks.

It is believed by American Expeditionary Forces that such an anti-aircraft weapon would be suitable not only for anti-aircraft machine-gun battalions, but as a protective anti-aircraft weapon for the use

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of divisional artillery brigades, corps artillery, anti-aircraft batteries, heavy artillery, railroad artillery, 240-millimeter trench mortar batteries, balloon companies, searchlight companies, and back-area defense, and that the needs of ammunition and supply trains could be satisfactorily met by supplying Browning automatic rifles.

One automatic rifle has been authorized for use from observation balloon baskets, but observers who have jumped from their balloons have not been fired upon during descent by parachute, provided they have not fired upon the attacking plane. They, therefore, feel that the small chance of bringing down an attacking plane by means of a single rifle does not offset elimination of machine-gun fire from the plane during parachute descent.

It may, therefore, be concluded that for anti-aircraft work it will be necessary to supply only one special type of gun which is certainly the ideal condition to be met.

The question of mounts is stated to be of equal importance with that of guns for anti-aircraft fire, and in addition to lightness in weight and the arrangement for the convenience of the operator, the requirements include free movement of the gun from below a horizontal plane to a vertical position, all around traverse and clamping of gun for use in barrage work.

Careful instruction and drilling in the use of sights is deemed absolutely essential, and it is believed that there is still a great deal of room for sight development.

As a means of fire control or of fire correction, it is considered by some that the development of special ammunition is of even greater importance. It will be borne in mind that with the present caliber the trajectories of the present special ammunition, particularly of the tracer and incendiary bullets, do not follow the trajectory of the service bullet beyond 600 meters and their course is therefore misleading. Delayed action special ammunition will not serve the purpose, as some of the firing occurs at ranges as short as 300 meters.

The consensus of opinion is that the best combination in sequence of anti-aircraft machine-gun ammunition, provided all the projectiles follow approximately the same trajectory, is one tracer, one service bullet, one incendiary, then a service bullet, then an armor-piercing bullet, and this combination be repeated. One recommendation has been made that the first 5 to 10 shots of a new belt should be tracer, in order to get on the target quickly.

The question of transportation for machine gun matériel merits much consideration. The Sechler trailers, designed in the United States for the transportation of this matériel, were not received in France, but a summation of comments made from photographs and descriptions was not in favor of this equipment.

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It was the opinion that a trailer was not a satisfactory means of transportation in a horse-drawn organization, as animals were scarce and the primary loads were already sufficient to tax their capacity. This objection does not exist in motor transportation. It is believed that the best method would involve the use of one of the standard machine-gun trucks, supplemented by light hand carts, preferably of folding type, to be carried in or underslung from trucks.

Emphasis was placed upon the necessity for training of personnel, and the best type of training target remains to be devised. The essential feature is to provide means for familiarizing the personnel with the great speed which is attained by planes. Toy balloons have been released from cliffs; a flag has been carried on a long bamboo pole attached to a motorcycle which runs at high speed along the top of a cliff at about 300 meters from the given position, the motorcycle being protected by a stone wall; the British employ a device by means of which miniature airplanes are trailed through the air at the ends of a long arm attached to a central spindle, which latter may be rotated by a motor at any desired speed. In connection with this device they use the Hyeth gun camera to record the marksman's aim. It is understood that there is being worked up in the United States a device similar to the Hollifield target rod.

As late as November 7, 1918, Brig. Gen. J. H. Rice, Chief Ordnance Officer, American Expeditionary Forces, stated in a communication to the Chief of Ordnance, that "* * * this branch of warfare may still be considered to be in its infancy, and, consequently, the equipment is still in the stage of development."

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Chapter VI.

PARTICIPATION OF THE UNITED STATES.

It is the intention of this chapter to deal with the participation of the United States in the development and furnishing of matériel, and not with the participation of the United States troops in the handling of this matériel.

The anti-aircraft artillery program of manufacture in the United States involved five separate projects or developments. The first of these covered improvised mounts, which were to be made by the Builder's Iron Foundry, Providence, R. I., and then shipped to France and there equipped with 75-millimeter French, model 1897, field-gun cannon, with recuperators and used for anti-aircraft purposes. These mounts were known as "Improvised anti-aircraft carriage, model of 1917," and are described in Ordnance Department Pamphlet No. 1699. The emplacement for this carriage was to be constructed by digging a circular excavation 109 inches in diameter and 67 inches in depth. The carriage is of the base-ring type, built in three sections to facilitate transportation, and the principal support for the carriage consisted mainly of two commercial channels to span the excavation. The gun and cradle were to be fastened on improvised mounts, at the same points at which they were fastened when assembled in the field carriage. In transportation, the gun is carried upside down on a trailer designed to receive it. Transportation was scheduled to be provided for gun, gun carriage, and the necessary lumber by three 1½-ton trailers with bodies of identical construction. To mount the gun or to dismount for transportation, chain blocks or a crane are required, and it has been stated in a report from overseas that two weeks were required to properly prepare the position and then mount the equipment in the field.

The first six of these improvised mounts were floated on November 23, 1917, and flotations were continued at intervals until the completion of the flotation program on April 17, 1918.

The first mounts were sent to Puteaux Arsenal and certain changes determined upon by the American Expeditionary Forces, which planned to have these changes made and the guns and cradles mounted either at Puteaux Arsenal or a factory in the vicinity. The changes involved the provision of azimuth graduations on the base traversing ring on which the channel iron frame traveled, and the addition of an elevation dial, each properly electric lighted, and certain changes

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in the platforms carried by the mount to permit of greater convenience in the handling and loading of the piece.

Sights were to be furnished by the French.

A report concerning these mounts, and the changes recommended, is on file in the Technical Staff Library.

The second project consisted of fifty-one 75-millimeter anti-aircraft truck mounts.[1]

The construction of this unit involved the application of an American model 1916 field gun cannon with a special type of hydrospring recoil mechanism with throttling valves cut into cylinders, placed on an off-set swivel mount, attached to the chassis of a White automobile truck. The gun was carried with the breech located directly behind the driver's seat, but as the length of recoil was 33 inches, the firing position was limited to such horizontal position of the mount as would permit of the gun recoil clearing the sides or the rear of the truck. It was necessary to stabilize the trucks by means of jacks before firing. This piece had a muzzle velocity of 1,828 feet per second and was arranged for high explosive and shrapnel, the former weighing 14.7 pounds and the latter 14.3 pounds. A 20-second (maximum) time fuze was employed with each. The maximum vertical elevation was 82° and with this elevation a vertical bursting ordinate of 5,980 meters was obtained. The minimum elevation was 31°, and with this elevation a vertical bursting ordinate of 1,750 meters was obtained. In both cases the bursting ordinates were limited by the time fuze. The cannon were manufactured at Watervliet Arsenal, save for the pilot, which came from Rock Island Arsenal, and the recoil mechanism were made by the New Britain Machine Co., of New Britain, Conn., who also assembled the complete equipments on the White truck. The first 6 of these units were floated August 25, 1918, and all but 7 were completed and freighted prior to the signing of the armistice; the delaying factor being the sights. A total of 30 had been floated prior to the signing of the armistice, and a total of 38 by December 12, 1918.

The third project included what was known in the Ordnance Department as the 3-inch anti-aircraft auto trailer, model 1918.[2] On this model, the main anti-aircraft program was centered. The cannon was of the ballistic design of the 3-inch 15-pounder, model 1898, seacoast gun, with an adaptation of the American model field gun breechblock of the drop block type.

A variable recoil mechanism was applied automatically adjustable for elevation, and at different elevations the recoils were approximately as follows: At 10°, 40-inch stroke; at 43°, 33-inch stroke; at 52°, 22-inch stroke; at 85°, 16-inch stroke. This recoil

[1] Handbook No. 1926. Revision prepared, but not printed.
[2] Handbook No. 2008. New handbook in preparation.

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was similar to that employed with the American model 1916 field gun, but with the use of a spear buffer on the counter recoil. This recoil mechanism is of the hydrospring type, and the variable adjustment of the stroke is governed by a rotating valve movement which closes or opens portholes drilled at an angle of 90° from the rotating surface. Through these holes a variable amount of oil is thus by-passed.

The mount permitted of all-around firing, and was bolted to the frame of a four-wheeled trailer truck, having springs, and solid rubber tires on the wheels. This truck was fitted with jacks and outriggers and the traveling weight of the complete unit was about 14,000 pounds.

The muzzle velocity of the piece was 2,400 feet per second and the projectiles included both shrapnel and high-explosive shell, each weighing about 15 pounds and arranged with a 23-second (maximum) time fuze. At maximum elevation of 85°, the bursting vertical ordinate limited by the time fuze was 7,200 meters. At minimum elevation of 10°, the projectile would strike the ground at 7,020 meters. At 23° elevation, the bursting vertical ordinate was 1,176 meters, and the horizontal ordinate 7,025 meters, both determined by the time limit of the fuze.

The contracts for the cannon were with the Chalkis Manufacturing Co., Detroit, Mich.; the trailer with Grant Motor Car Corporation, Cleveland, Ohio; the mounts and assembly with New Britain Machine Co., New Britain, Conn.; the sight mounts with the same company; the telescopes with Kollmorgan Optical Corporation, Brooklyn, N. Y.

Although one unit had been tried out at the proving ground, none of this model were completed and finally accepted up to the signing of the armistice. The delay centered around the valve of the recoil mechanism, although no sights were expected until December. The valves were planed and not lapped, and while a fairly smooth surface was obtained laterally with the stroke of the planer, an uneven surface was obtained between the planer tool cuts, with a resultant cutting of the piston. Finally a recoil was taken to another shop and a satisfactory valve surface obtained by broaching, but this recoil was not finished until December 1, 1918. At this time about 80 cannon had been completed and accepted, about 300 mounts were in course of construction and about 25 were on the assembling floor, and it was assumed that this latter number could be finished up in a comparatively short time after the valve difficulty was overcome. (On Mar. 27, 1919, the total of the cannon accepted was 167 and of the trailer mounts 18.)

The total requirements for this model had been placed at 1,709, of which the requirements to December 31, 1918, called for 1,239. The

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total number of cannon on order was 1,100 and mounts 612, but a change in the requirements figures was under discussion.

The fourth anti-aircraft project consisted of 160 3-inch anti-aircraft guns, model 1917, with seacoast mounts.[1] These were beautiful and powerful weapons, arranged with 12-inch recoil and designed to be mounted on a solid concrete base about 2½ feet thick and 18 feet in diameter. These guns were designed prior to the entrance of the United States into the war, and were intended for seacoast defense. The muzzle velocity was 2,600 feet per second; both high-explosive shell and shrapnel were to be employed; weight of projectile was 15 pounds, with time fuze; maximum horizontal range without the time fuze functioning, 12,000 meters; and vertical range without time fuze functioning, 8,300 meters.

These guns were intended for seacoast defense and for the defense of depots, and it was not the intention to send them to France. Five of them were mounted experimentally on heavy gasoline trucks, and in June, 1918, the following interchange of cablegrams occurred between Ordnance and American Expeditionary Forces. On June 7 Ordnance cabled:

There have been delivered 55 anti-aircraft mounts, model 1917, seacoast type, with 3-inch guns, and 104 additional mounts, with guns, are nearing completion and can be delivered at intervals throughout this year. This gun fires a 15-pound projectile with muzzle velocity of 2,600; maximum horizontal range, about 16,500 yards; maximum vertical range, about 8,000 yards; maximum elevation, 85°. The gun has semiautomatic breechblock. Weight of gun and pedestal is 15,300 pounds, and can be mounted for all-around fire on a circular concrete block 18 feet in diameter by about 30 inches in thickness. These dimensions subject to change. Mount is shown on drawings 5–26 and gun on drawings 31–55, complete sets being sent you. A heavy gasoline truck has also been built on which this gun and mount can be transported and fired. Weight of this truck is 18,000 pounds; stability is very good, and the material is found quite satisfactory for use on good dirt and macadam roads. Only five of these trucks on hand, but factory deliveries could probably be started in from two to three months at a rate of three a week. Do you desire shipment of this matériel with or without trucks for protection of depots and similar purposes?

Crossing this cablegram, on June 8, Pershing cabled:

It is understood that there is available in the United States a number of 3-inch, model 1917, anti-aircraft guns and mounts designed for coast defense. It is believed these guns would be very valuable for use in France. Please state whether or not they are available and in what quantity. Is suitable ammunition also available?

On June 26 Pershing cabled:

With reference to paragraph 3L, your cablegram 1493, it is not desired that 3-inch anti-aircraft guns, model 1917, seacoast type, be shipped to France. Sixty 75-millimeter on improvised mounts now here with fifty-one 75-millimeter trucks, all of which it is understood will be completed in July, and 3-inch on

[1] Handbook, 1808. New handbook in preparation.

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auto trailers, deliveries of which, it is understood will, commencing with 12 in July, meet our needs. Every effort should, however, be made to secure earliest possible delivery on remainder of 3-inch on auto trailers to include the 200 for the Service of Supply and the 60 for the First Army as per paragraph 1L, your cablegram 1096.

This latter cablegram disposed of all thought of sending this model of anti-aircraft gun to American Expeditionary Forces in any form. The guns were therefore distributed in the United States and to the Canal Zone on the Isthmus of Panama. Guns were made by Watervliet Arsenal and 22 of the mounts by Bethlehem Steel Co., and the balance by Watertown Arsenal, and between 90 and 100 complete units had been finished and accepted at the time of the signing of the armistice, although some of the sights were not to be available until December. (On Mar. 27, 1919, the total of the cannon accepted was 102 and of the mounts 112.)

The fifth anti-aircraft project had to do with a 4.7-inch anti-aircraft gun, although it can hardly be said to have reached the stage of a project. The desire for a 4.7-inch gun on a split-trail carriage, to be used against aircraft was first expressed by Gen. Pershing on September 6, 1917, in cablegram No. 139, paragraph 6.

The first work done by the Ordnance Department on a gun larger than 3-inch, for anti-aircraft work had been on the design of a 3.8-inch gun and carriage. Work on the general design of this 3.8-inch unit was started in August, 1917. (See memo. CA 3/42, dated Aug. 9, 1917, to the Gun Division.) Following Gen. Pershing's cablegram of September 6, his cablegram No. 175, paragraph 10, of September 23, 1917, called attention to the need of a larger caliber than 3-inch for effective anti-aircraft work, and on September 27 Ordnance cabled (222–1) notifying him that a larger caliber gun had been started and requesting recommendation as to ballistics, and in 224–16 he was informed that thirty-six 4.7-inch guns with split trail would be available in the spring of 1918.

On September 28, Pershing cabled (185–8) repeating the request for batteries of three 4.7-inch guns with split trail, arranged for a 45-pound projectile, to be sent about November 1. On October 10, 1917, the Gun Division submitted designs for a 3.8-inch gun weighing 5,250 pounds and on October 11, Pershing replied to Ordnance Department's request of September 27 regarding ballistics (213–3), recommending French guns with a muzzle velocity of 2,300 feet per second, high-explosive shell, weight 40 pounds, rate of fire 10 rounds per minute, automatic loading.

There was further discussion as to caliber and ballistics and weight of projectile, but the availability of guns was the first consideration, and reference was made to the new French 105-millimeter

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anti-aircraft gun, being carried on two wheels, and having its running gear removed when gun was set in position by lowering the platform to the ground on 4 jacks.

The outline finally settled down in January, 1918, to a 4.7-inch gun mounted on a caterpillar trailer with jacks and outriggers known as 4.7-inch anti-aircraft gun, model of 1918, on 4.7-inch anti-aircraft trailer mount, model E, having an elevation of 80°, muzzle velocity of 2,400 feet per second, with a 45-pound high-explosive projectile, with time fuze for maximum altitude of 10,000 meters at 80°, and maximum horizontal range of 15,000 meters, in both cases without the functioning of the fuze; weight of carriage, 18,000 pounds; weight of caterpillar, 10,000 pounds; weight of detached floats, etc., 2,000 pounds; total traveling weight of mounts, 35,000 pounds; gun arranged for all-around fire.

Order for the gun was placed with Watervliet Arsenal. On January 16, 1918, purchase order CA 54 was given to New Britain Machine Co., New Britain, Conn., for an experimental recoil mechanism and mounting, together with assembling, and at about the same time an order was given to the Holt Manufacturing Co., of Peoria, Ill., for the caterpillar trailer.

Practically all details were settled at the time above indicated, with the exception of those pertaining to the request for automatic loading. Attempts were made to obtain the details relating to the Schneider loading device, which had been developed by the French for their 105-millimeter anti-aircraft gun, as this had apparently been developed successfully after two years of work, and would thus be immediately available. General arrangement drawings of this device were received, but not details, and finally a loading device was designed in the United States, and these designs were in readiness about July.

A 4.7-inch cartridge, with projectile, forms a large and heavy piece (weighing something over 70 pounds), to be handled by an automatic loading device, and a material problem was involved. With this attachment, the recoil of the gun cocks the loading mechanism, and on the return of the gun to battery, the breech is opened by hand and the cartridge case automatically ejected, and on a separate lever being released by hand, the automatic loading device places the new cartridge in position and closes the breech, and the piece is then ready for firing by means of the firing handle. The principle of the automatic loading device involves the striking of a lug by a projection on the breechblock, at the time of recoil, and the recoil action thus draws back an actuating rod against spring pressure. On the return of the gun to battery the rod is retained by a catch with the spring in compression. A cartridge is then placed by hand in the opening of the breech, being retained there, with the gun

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at high elevation, by a small lip or tray hinged to the breechblock operating handle. A small spade attached to the automatic loading rod is then pressed down by hand until its lower edge projects past the upper rim of the cartridge, when it releases the catch holding the rod and permits the compressed spring to expand, which throws the shell into the breech and in so doing releases the breechblock, which flies upward and closes the breech, and in so doing the breechblock handle connection lowers the aforementioned lower lip or tray.

At the time that the development of this anti-aircraft unit was initiated, the hydrospring recoil mechanism was the only type available, but a hydropneumatic recoil of the St. Chamond type will eventually replace this, and at such time the loading device will probably be changed to some better type.

Instead of the cannon being balanced, for weight, at the trunnions, in this experimental unit, the trunnions were not located at the center of gravity of the cannon and cradle, but nearer to the breech, with the gun in battery. The balance was then obtained by providing cams at the breech end of the cradle, to which link chains were attached, and led to horizontal spring cylinders attached to the sides of the carriage. The shape of the cams was designed to so supplement the deficiency of weight on the breech side of the trunnion centers as to provide a mechanical balance at any angle of elevation of the gun. As this unit was arranged for all-around fire, the recoil of the gun when at high elevation was toward the floor of the trailer and the purpose of this offset trunnion arrangement was to keep the trunnion centers as low as possible and still provide sufficient vertical distance for recoil. While the unit appears to be stable, it presents a somewhat top-heavy appearance, and future units may be provided with larger trailers.

The caterpillar trailer was shipped by the Holt Co. to New Britain on June 18, but the cannon was not in readiness until October, and thus, in connection with the completion of the automatic loading attachment and work on a sighting device which would permit of keeping the eye on the target while the gun was pointed at a sufficient angle to allow for the movement of the airplane, prevented the completion of the experimental unit prior to the signing of the armistice.

Total length of gun, 201.5 inches; length of rifled portion of the bore, 163.2 inches; length in calibers, 40; weight of full powder charge about 11 pounds; minimum elevation permitted by carriage, 0°; maximum elevation permitted by carriage, 80°; type of recuperator, hydrospring; weight of gun and breech mechanism, 6,945 pounds. Long recoil, 36 inches; ports begin to close at 45°; long recoil, 36 inches, ports closed at 49° 40′; intermediate recoil,

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24 inches; ports begin to close at 69° 49′; intermediate recoil, 24 inches; ports closed at 74° 42.25′; short recoil, 20 inches to maximum elevation, 80°.

AMMUNITION.

Of the anti-aircraft artillery ammunition manufactured in the United States, 75-millimeter shrapnel only was available at the time of the signing of the armistice. Of this the total accepted was 452,007 rounds; docked, 324,772 rounds; and of the latter number 103,254 rounds had been floated.

FIRE CONTROL.

It has been made evident that a large part of the success in handling anti-aircraft artillery must depend upon a properly worked out theory and application of fire control. Reference has been made to the methods and instruments used in France, and further comment is included in Chapter VIII.

While the apparatus was not completed in season to be of use in the European war, a new and original system of anti-aircraft fire control had been developed and described in detail in "Report of development of the Spherographic System of Anti-aircraft Fire Control," by Maj. James M. Boyle, Ordnance Department, Engineering Division, dated November 5, 1918, on file in the Technical Staff Library.

In the preface to this report it is stated that the principal functions of anti-aircraft artillery consist in minimizing the effectiveness of aircraft in hostile bombing operations and as eyes of the enemy, and that the new system has been developed with the object of simplifying anti-aircraft gunnery in the field, and greatly increasing the accuracy of fire. From a record of "hits" referred to on pages 74 and 75, inclusive, of this report, certain deductions are drawn, but from the record cited on page 82 of the present history it is evident that our forces in the field had reached a much higher state of efficiency, with the apparatus at their disposal, than was generally appreciated at the time that the above-mentioned admirably prepared report was submitted.

In a separate "General Report on Anti-aircraft Fire Control Systems," dated December 5, 1918, it is stated that:

> The angle of approach method is crude and only quasi-scientific.
>
> The tachymetric method is overdeveloped scientifically. Its apparatus contains too many small, interdependent parts (the anti-aircraft sight which is used on the 3-inch anti-aircraft trailer mounts has about 125 parts). It is an indirect method, having the intermediate steps in the development of the final result concealed in the intricacies of delicately pivoted, low torque, indicating instruments, etc. The most modern development of the tachymetric system (the V. C. corrector), while still complicated and its mechanism composed of

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many small parts, does make one radical step toward simplicity in that it does not require sights on the guns.

The spherographic method, developed in this organization (untried in the field), approaches the simplicity of standard coast-artillery practice in that there are no sights on the guns and in that the settings in azimuth and elevation and the fuze setting are determined by apparatus in which any deviation of the flying target from its predetermined course is immediately obvious and readily corrected. A distinctive feature of the spherographic system is that an accurate, permanent record is necessarily left of the efficiency of each firing operation of the controlled batteries.

It will be decidedly interesting, but most difficult, to compare the results obtained with this new system with the results obtained through the use of apparatus which was available for test under combat conditions.

ANTI-AIRCRAFT MACHINE GUNS.

The manner of participation by the United States in that part of the anti-aircraft program which was occupied by machine guns is possibly best described by photographs, of which a number are attached to this report. As to the machine guns themselves, which were manufactured in the United States, it will be borne in mind that they could be employed for several different purposes, and that their adaptation for anti-aircraft work was largely a matter of sights, special stocks, ammunition cases, special radiators to avoid the use of water-cooling, mounts, pedestals, ammunition, and transport equipment.

The actual number of machine guns produced, for all purposes, may be obtained by reference to the report on machine guns and small arms.

The ammunition for machine guns employed in anti-aircraft service was also in a large degree similar to that employed in machine guns used for other purposes. Information as to production for all purposes may be obtained by reference to report on machine-gun and small-arms ammunition.

A great variety of design and experimentation was undertaken in the United States, on the basis of experience obtained in France, and such matériel as became at all standard is described in elaborate detail, and profusely illustrated, in a collection of data which has just been completed by Ordnance Department under the title of "Handbook of Anti-aircraft Matériel for Machine Guns. Description and Instruction. Small Arms Division, Ordnance Department."

The development work undertaken was diversified and dealt with so many small parts that no useful purpose would be served by attempting an elaborate description in this chapter. The needs have been referred to on previous pages and as the specific data necessary to new design reached the United States at a comparatively late

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date but comparatively little of the special equipment from the United States got overseas prior to the armistice. It will be remembered that in the early operations by the American troops, their equipment was furnished from France, and that it was only after the American troops actually got into action that they were able to suggest certain improvements as the result of experience, and that this left but little time in which to design, develop, manufacture, and ship new devices, resulting from these suggestions. The equipment actually shipped overseas included 300 Cygnet trailers and 383 Cygnet mounts, with Lewis, Browning, and Vickers adapters for each mount. Since the armistice, 566 additional trailers and 50 adapters have been distributed in the United States.

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Chapter VII.

CABLEGRAMS.

ANTI-AIRCRAFT ARTILLERY.

On March 5, 1918, Pershing cabled (682–1):

With reference to paragraphs 2 A and B, your cablegram 785, anti-aircraft gun equipment for army of 30 divisions should include 60 mobile mounts with 75-millimeter guns, 40 semi-mobile with 4.7-inch guns. The number of anti-aircraft guns is governed by tables of organization. The probable number of 37-millimeter automatic anti-aircraft guns can not be considered until satisfactory model has been produced and tested. If this gun can be made genuine automatic with tracer ammunition it will have great value and should be supplied in considerable numbers. If not genuine automatic it will have but small value. With reference to subparagraph A, anti-aircraft guns required for lines of communication and service of the rear should be principally of semifixed type. Total number required can not be foreseen and must depend upon number and location of activities and the extent to which the enemy carries his bombing operations. The 50 improvised mounts now being completed could all be profitably installed at present date. A manufacturing program of at least 200 of these or similar mount should be undertaken. In this connection, the purpose intended for 612 semimobile mounts for 3-inch guns shown in your program of manufacture not clearly understood. If these mounts can be adapted to semifixed conditions and arranged to carry 75-millimeter guns they should be satisfactory for protection of service of the rear activities. With reference to subparagraph B, the only 75-millimeter anti-aircraft guns now on order are for the 50 semifixed mounts being finished in United States. The comparatively small number of anti-aircraft mounts and guns obtainable from the French during 1918 will not materially assist the American Expeditionary Forces' project. French anti-aircraft service is way behind in its own program.

On March 18, Ordnance cabled (949–1–F):

Reference your 697, paragraph 2. No. 3-inch (anti-aircraft, see 697) trailers and 75-millimeter truck mounts will be shipped to France during March. Estimated docked deliveries as follows: 75-millimeter truck mounts, April, 2; May, 10; June, 20; July, 19. Three-inch anti-aircraft trailers, May, 3; June, 20; July, 60; August, 70. Trouble may develop during proof-firing which may cause delay in deliveries. Any change in above deliveries will be cabled.

On March 20 Pershing cabled (749–1–B):

For the Chief of Staff. With reference to paragraph 1, your cablegram 913, it is not desired to begin manufacture of any improvised mounts, if 3-inch guns on auto trailers can be obtained sooner. Information desired as to date when 3-inch guns, 2,400 foot-seconds, on auto-trailer carriages, model 1917, may be expected for delivery and at what rate per month.

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On March 26, Ordnance cabled (1010–1–B):

Reference yours 749, paragraph 1–B. It is estimated 3-inch anti-aircraft guns will be completed and proved and ready for issue as follows: June, 6; July, 14; August, 30; September, 50; October, 75; November, 75; December, 75. Production of carriages ahead of guns and carriages will be ready for numbers specified.

On April 6 (1071–1–C):

Reference your 796, paragraph 5–C. Three-inch anti-aircraft guns with trailer mounts estimated deliveries in France as follows: July, 6; August, 14; September, 30; October, 50; November, 80; December, 80.

On April 9 (1096–1–L):

Reference your 796, paragraph 5–C. Our plans regarding anti-aircraft guns of 3-inch or 75-millimeter caliber proceeding on following basis: Regular equipment per Army, 60 3-inch guns with corps troops and 200 3-inch guns for line of communication and service in rear; these all 3-inch 2,400 foot-second guns on semimobile auto-trailer mounts; additional equipment for total American Expeditionary Forces, 103 75-millimeter guns; these all field guns, 50 on improvised mounts and 51 on truck mounts, with 1 additional mount of each type retained for proving grounds in United States. It is assumed that these 75-millimeter anti-aircraft guns are in addition to standard 3-inch gun; do not vary with number of troops and will not be increased. Should provision be made for replacing losses of 75-millimeter field guns on truck and improvised mounts? Should rate of fire for 3-inch anti-aircraft guns with corps troops recommended in your 507, paragraph 6, apply to guns in lines of communication and service of rear?

On April 11 (1109–2–F):

Reference your 837, paragraph 3–B. Later statement of probable delivery of 3-inch anti-aircraft guns given in our 1010, paragraph 1–B, will be followed in providing ammunition; not our previous 949, paragraph 1–F.

On April 21 Pershing cabled (973–2):

With reference to paragraph 1–L, your cablegram 1096, replacements of losses occurring on the 50 improvised 75-millimeter anti-aircraft guns can be secured in France. Replacements of losses on the 50 75-millimeter anti-aircraft guns on truck mounts must come from United States. Thirty rounds is the present calculated expenditure per fires a day for all 75-millimeter anti-aircraft guns in service with American Expeditionary Forces. Additional quantities of anti-aircraft-gun equipment may be required in the future; because of expansion in our operations we can not discount these requirements at present.

On May 11, Ordnance cabled (1307–1–H):

Reference your 1049, paragraph 8B. All maximum ranges given for 40° elevation 75-millimeter model 1916 on anti-aircraft truck mount, maximum 10,000 meters, maximum elevation 84°, corresponding maximum ordinate 6,850 meters, anti-aircraft shell or shrapnel; 3-inch anti-aircraft gun model 1918, maximum 13,700 meters, maximum elevation 85°, corresponding maximum ordinate 9,100 meters, anti-aircraft shell or shrapnel; 4.7-inch anti-aircraft gun model 1918, maximum 13,700 meters, maximum elevation 80°, corresponding maximum ordinate 9,1000 meters, anti-aircraft shell or shrapnel.

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On May 20, Pershing cabled (1148–6–A):

With reference to paragraph 1F, your cablegram 949, request information as to status of 51 improvised truck mounts for 75-millimeter or 3-inch anti-aircraft guns. No recent reports of expected deliveries of ordnance material has included this item. Request at the same time complete statement of what anti-aircraft artillery will be actually ready at seaboard for floating during July.

On May 21 (1159–1):

With reference to paragraph 2A, your cablegram 969, and paragraph 1C, your cablegram 1272, following quantities have been ordered prior to January 1, 1918: Anti-aircraft guns, one 1-pounder, 14-millimeter; 14 guns, 75-millimeter; anti-aircraft guns, 4 guns, 75-millimeter. This includes all items ordered from British and French Governments in Washington. It is estimated that there will be ordered during the balance of the year 1918 * * *. It is estimated that the amount of funds required for payment is as follows: For material ordered prior to January 1, anti-aircraft guns, $20,000. Against these items following funds have been allotted from Washington to Finance Division, Office of Chief Ordnance Officer, American Expeditionary Forces, for period December 19, 1917, to April 30, 1918, according to records of the Finance Division here * * * anti-aircraft guns, Army, 1917–18, act June 15, 1917, $350,000; ammunition, anti-aircraft guns, Army, 1917–18, act of June 15, 1917, $1,000,000, armament of fortification. * * * The following requests for additional allotments have been made by cable on dates specified and when granted are to be considered in addition to the above, March 13, No. 716, paragraph 2A, ammunition for anti-aircraft guns, balance, $2,600,000 * * *.

On May 23 (1168–1):

Following allotments and priority schedules for the Army service for June. With reference to paragraph 2, your cablegram 1304, 300 caissons and limbers for 75-millimeter guns.

On May 22 (1167–1–F):

With reference to paragraph 1L, your cablegram 1096. Would advise that allowance of 30 rounds per day for anti-aircraft guns should be maintained for those guns assigned to army and corps troops, namely, 60 3-inch guns on trailer mounts and 59 75-millimeter guns on truck mounts; that it is considered safe to reduce the daily allowance for the guns on line of communication and the service of supplies to 20 rounds per day. For program outlined in cable this would mean a daily allowance for the full manufacturing program of 5,800 rounds per day of 3-inch ammunition and 2,500 rounds per day of 44-millimeter ammunition. All guns on improvised mounts of the semifixed type will be used in the line of communication defense. The 51 75-millimeter guns on truck mounts will probably be used at or near front-line positions, where considerable activity will exist.

On May 27, Ordnance cabled (1406–1):

Reference your 1148, paragraph 6A: Fifty 75-millimeter anti-aircraft improvised mounts floated up to middle of May. These mounts for use with the 75-millimeter French guns, model 1897, and recuperators ordered in France. Expected seaboard deliveries of 51 anti-aircraft truck mounts complete with guns as follows: July, 20; August, 20; September, 11. These truck mounts to

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be used with 75-millimeter American type gun, model 1916. Expect to deliver to seaboard during August, 5 3-inch anti-aircraft guns complete with auto-trailer carriages; none ready for floating during July. This cancels promise given in our cable 949, paragraph 1, subparagraph F.

On May 29, Pershing cabled (1205–2):

Has production on model 1917 telescopic sights for the model 1917 anti-aircraft improvised mounts been actually started? Cable estimated deliveries at seaboard. (2) Has consideration been given in conjunction with sighting apparatus to supplying from America a fuze-setter disk with its proper operating for such duty in order to give superelevation on the improvised anti-aircraft carriage, model 1917.

On May 30, Ordnance cabled (1421–3D):

Reference your 895, paragraph 1B. Shall we supply from this country amortisseurs for 51 improvised anti-aircraft mounts?

On June 3 (1456–1):

It is understood that you want 75-millimeter anti-aircraft improvised truck mounts and it is expected that 12 truck mounts can be shipped.

On June 5 (1463–1–C):

Reference your 1205, paragraph 2. Telescopic sights, model 1917, for 75-millimeter anti-aircraft improvised mount, model 1917, none completed to date; estimated seaboard deliveries, July, 30; August, 30.

On June 5, Pershing cabled (1248–1–C):

With reference to paragraph 3D, your cablegram 1421. All amortisseurs for the 51 improvised anti-aircraft mounts will be supplied by the French Government.

On June 7, Ordnance cabled (1493–3–L):

There have been delivered 55 anti-aircraft mounts, model 1917, seacoast type, with 3-inch guns, and 104 additional mounts with guns are nearing completion and can be delivered at intervals throughout this year. This gun fires a 15-pound projectile with muzzle velocity of 2,600; maximum horizontal range about 16,500 yards; maximum vertical range about 8,000 yards; maximum elevation 85°. The gun has semiautomatic breechblock. Weight of gun and pedestal is 15,300 pounds, and can be mounted for all-around fire on a circular concrete block 18 feet in diameter by about 30 inches thickness; these dimensions subject to change. Mount is shown on drawings 5–26 and gun on drawings 31–55, complete sets being sent you. A heavy gasoline truck has also been built on which this gun and mount can be transported and fired. Weight of this truck is 18,000 pounds; stability is very good, and the matériel is found quite satisfactory for use on good dirt or macadam roads. Only 5 of these trucks on hand, but factory deliveries could probably be started in from two to three months at rate of 3 a week. Do you desire shipment of this matériel with or without trucks for protection of depots and similar purposes?

On June 8, Pershing cabled (1270–2–H):

It is understood that there is available in the United States a number of 3-inch, model 1917, anti-aircraft guns and mounts designed for coast defense. It is believed these guns would be very valuable for use in France. Please state

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whether or not they are available and in what quantity. Is suitable ammunition also available?

On June 13, Ordnance cabled (1541–1–B):

Reference your 948, paragraph 1J, superseding our 1364. Factory deliveries guns and carriages based on limiting items as follows: 3-inch anti-aircraft guns and autotrailer carriages, expected deliveries, June, none; July, 12; 75-millimeter, model 1916, mounted on truck for anti-aircraft use, to June 1, 18; June, 15; July, 18.

On June 26, Pershing cabled (1375–1–C):

With reference to paragraph 3L, your cablegram 1493, it is not desired that 3-inch anti-aircraft guns, model 1917, seacoast type, be shipped to France. Fifty 75-millimeter on improvised mounts now here with 51 75-millimeter on trucks, all of which, it is understood, will be completed in July and 3-inch on auto trailers, deliveries of which, it is understood, will, commencing with 12 in July, meet our needs. Every effort should, however, be made to secure earliest possible delivery on remainder of 3-inch on auto trailers to include the 200 for the Service of Supply and the 50 for the First Army, as per paragraph 1L, your cablegram 1096.

On July 5, Ordnance cabled (1673–11–D):

Reference your 1375, paragraph 1C. No 3-inch anti-aircraft guns on auto trailers will be proof-fired in July and probably less than 12 in August. Will cable expected deliveries as soon as first gun proof-fired on trailer.

On same date (1688–1):

The following is a list of the principal items of ordnance matériel floated during the month of June: Twenty 75-millimeter anti-aircraft truck mounts.

On July 10, Pershing cabled (1443–3–D):

Ordnance status on European orders as of July 1. Items will be listed as follows: Totals on hand in France all sources; amounts received on European orders since June 15; new orders accepted or canceled in Europe since June 15; promised deliveries by numbers and months; 75-millimeter anti-aircraft; 39; 0; none; 12 July. * * *

On July 26, Ordnance cabled (1791–7–J):

Reference your 1375, paragraph 1, subparagraph C, and our 1406, paragraph 1, and 1541, paragraph B. Regarding 75-millimeter anti-aircraft truck mounts, difficulty with sights has prevented July shipment. Hope to complete entire 51 in August and float, August, 40; September, 10; holding 1 here.

On July 27, Pershing cabled (1507–1–2):

Ship during August and following order of priority: Fifty-one 75-millimeter anti-aircraft mounts, model 1916; 12 trailers, 3-inch anti-aircraft; 48 trailers for 3-inch anti-aircraft.

On July 19 (1581–4):

With reference to paragraph 1, your cablegram 1609. Consider that the 2 anti-aircraft machine guns now issued each battery are sufficient. Railroad batteries should have 4 anti-aircraft machine guns per battery as indicated in paragraph 3A, my cablegram 1471.

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On August 9, Ordnance cabled (Courier X 5–2–C):

The following items can probably be floated in the quantities indicated: Forty 75-millimeter anti-aircraft mounts, model 1916. The following items will probably not be floated in August for reasons indicated: Sixty trailers, 3-inch anti-aircraft, awaiting proof-firing of pilot gun.

On August 10, American Expeditionary Forces cabled (S–3–5):

Reference paragraph 1, your cablegram 1801. Ordnance status of European orders as of July 31. Items will be listed as follows: Total on hand in France, all sources; amount received on European orders since July 15; new orders accepted in Europe since July 15; promised deliveries by number and month: 75-millimeter anti-aircraft, 39; none; none; 12 August.

On August 22 (S–38–1):

Ordnance status on European orders as of August 15. Equipment listed thus: Item; depot stock; received in depot from European sources since August 1; new orders accepted in Europe since August 1; promised deliveries by number and months; received on European orders since August 1; new orders accepted in Europe since August 1; promised deliveries by numbers and months: 75-millimeter anti-aircraft guns, 23; none; none; 28 August.

On August 23, American Expeditionary Forces cabled (S–40–3–D):

Request advice as to best docked deliveries by months through June, 1919, trailer mounts for 3-inch anti-aircraft guns. Also number on procurement.

On August 26, Pershing cabled (1627):

Due to critical situation existing until recently 5 out of 6 divisions arriving in France have been used as combat divisions and replacements have been handled, through base divisions and provisional replacement depots, without the intermediaries of replacement divisions, contemplated by original American Expeditionary Forces' organization project. Experience thus gained shows that original organization project may profitably be modified by omitting replacement divisions but continuing one base depot division in each group of six divisions. Summarizing the above, I recommend that replacement divisions be omitted; that one base depot division be provided in each group of 6 divisions; that corps troops be provided for each 4 combat divisions; that army troops be provided for each 20 combat divisions, as contemplated by the original American Expeditionary Forces organization project and approved modifications thereof. Reorganization of first 36 divisions on this basis calls for following additional corps troops to complete 7 corps by transfers and adjustments to be made here: * * * one 3-inch anti-aircraft battalion * * *, one anti-aircraft machine-gun battalion. All of above should be shipped not later than October 31. Whatever the number of available combat divisions and whatever the size of each army required to meet any particular situation, the necessary distribution of the total available army troops can be made according to the necessities as they arrive.

On September 3 (1652), amplification of cablegram 1627:

Incident to increase in number of corps. Following additional are also necessary: One torch anti-aircraft battalion, one anti-aircraft machine-gun battalion.

On September 4, Ordnance cabled (X–56–1–C):

Reference S–40, paragraph 3D. Total number trailer mounts for 3-inch anti-aircraft guns on procurement 612. Project now in experimental stage.

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First carriage to be proof-fired in about one month. If successful, following monthly dockage expected through June, 1919: November, 12; December, 20; January, 30; February, 40; March, 50; April, 60; May, 60; June, 30.

On September 6, American Expeditionary Forces cabled (S–95–1):

Ordnance status on European orders as of August 31. Artillery listed thus: Item; on hand in France; received on European orders since August 15, which will not correspond in all cases with report of August 15, due to certain corrections in on-hand figures; new orders placed in Europe since August 15: 75-millimeter anti-aircraft guns, 28; 1 and 4 on old orders not previously included; none; 27 September.

On the same date (S–97–1):

Reference X–27, paragraph 1–E. Status from July 1 to July 15 given in courier P–60. Following is as of August 31, giving items: Total ordered from European sources; total received to August 31 from European sources: 75-millimeter anti-aircraft guns; 4 complete units and 51 guns only; 4 units of 24 guns only; these are corrected figures.

On September 10 (courier X–11–7):

Following is a list of the principal items of Ordnance stores floated in August, with a statement of ordered, freighted, and docked as of August 31: 75-millimeter anti-aircraft guns; ordered 16, freighted 4, docked 2, floated 2.

On September 12, Ordnance cabled (X–90–3–D):

This supersedes A–1791, paragraph 7J. Regarding 75-millimeter anti-aircraft truck mounts, experiencing difficulty with sights. Floated August, 2; will float September, 18; and if difficulties with sights are overcome, expect to float, October, 30; holding 1 here.

On September 18, Pershing cabled (1701–1):

Reference P–1678, the following program is recommended for the next 300,000 troops to be shipped. This is considered as the program for December. * * * 5 batteries, anti-aircraft guns, semimobile, 1 3-inch anti-aircraft battalion. Paragraph 3. Corps troops: 1 anti-aircraft machine-gun battalion.

On September 27, Ordnance cabled (X–120–1–A):

The quantities below are the amounts which it is estimated will be available for flotation during the month of October: 3-inch anti-aircraft gun and trailers, none; have available 20 75-millimeter anti-aircraft truck mounts.

October 5 (X–154–6):

Superseding A–1796, paragraph 6D, telescopic sight, model 1917, for 75-millimeter anti-aircraft improvised mounts. Manufacturing difficulties encountered. Now estimate factory completions 30 in October.

On October 11, American Expeditionary Forces cabled (S–238–1):

Ordnance status on European orders as of October 1. Artillery listed thus: Item; total on hand in France; received on European orders since September 15; promised deliveries by numbers and month; 75-millimeter anti-aircraft guns; * * * complete materials; 27 guns only; none; none.

October 9 (S–251–3–D):

Request complete shipping data, including names of vessels, on all improvised anti-aircraft mounts. Records show receipt of 48, 8 of which are incomplete.

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On October 12 (S–271–D):

Ship during November in following order of priority: 13,000 rounds 75-millimeter anti-aircraft high-explosive shells; 10,000 rounds 3-inch anti-aircraft high-explosive shells; 23,000 rounds 75-millimeter anti-aircraft shrapnel; 50 improvised 75-millimeter mounts.

On October 14 (S–284–3–F):

Please cable expected delivery in France of sight, model 1917, for improved anti-aircraft mount (2) and send by next courier drawings, class 15, * * * 15. * * * , drawings 3.

On October 15, Ordnance cabled (X–178–1–B):

Reference S–251, paragraph 3–D. Fifty improvised anti-aircraft truck mounts floated on steamer *Osage*. P–1375, paragraph 1C, acknowledges receipt of these. White anti-aircraft truck mounts, complete with guns, have been floated as follows: 6 on *Texan*, 6 on *Western Front*.

On October 19 (X–181–1):

Following is a list of the principal items of ordnance stores floated in September with a statement of ordered, freighted, and docked as of September 30: 75-millimeter anti-aircraft guns; ordered 30, freighted none, docked none, floated 12. Please advise of any other items on which you want monthly cables. This answers S–237, paragraph 1G. GOETHALS.

On October 23, American Expeditionary Forces cabled (S–330–2–F):

Please send all available information on equipment of battery of anti-aircraft trailer mount and anti-aircraft truck mounts. Summary of information requested by cable, details by courier. Information especially desired as to method of carrying ammunition for both types of mounts. Is table of organization, No. 107, series B, being followed for trailer mounts, and what changes in the table are contemplated for truck mount? What is present status of production on this material?

On October 25, Ordnance cabled (X–215–1):

The following are the quantities which the Ordnance Department expects to have available to float in November: Item of improvised 75-millimeter mounts already shipped; if you mean 75-millimeter anti-aircraft truck mounts, 14 were floated September; expect to float 20 or more October, and balance in November; 10 3-inch anti-aircraft gun units.

On October 21 (X–218–1–D):

Reference S–284, paragraph 3F, and superseding X–154, paragraph 6. Sight, model 1917, for improvised anti-aircraft mounts; expect to freight 60 end of December.

On October 29, American Expeditionary Forces cabled (S–367–5–A):

Please cable expected deliveries in France of sight, model 1917, for improvised anti-aircraft mount.

On October 31, Ordnance cable (X–235–9):

Superseding A–2006, paragraph 5, and X–90, paragraph 3D, regarding 75-millimeter anti-aircraft truck mounts. Unable to float entire 30 in October.

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About 20 of this number are now docked and the balance are expected to be docked about middle of November.

On November 1 (X–240–2):

Reference S–2330, paragraph 2F. Present equipment of anti-aircraft batteries of both truck and trailer mounts is based on tables of organizations 107 and 108, series B. Eleven trucks, ammunition type, are specified with each 3-gun battery. For trailer mount batteries 3 of these are used for towing and personnel. For truck mount batteries these 3 will be used for personnel or as required. In accordance with A–1425, paragraph 1D, the fire-control truck specified in tables of organization will be replaced by a 2½-ton tractor and the 6-horse reel and cart. One of the 5 passenger motor cars in each battery will be replaced by a reconnaissance car and 1 staff observation car added to battalion headquarters. Ammunition trucks carry ammunition in the original containers and each truck also carries 4 pigeonhole chests, one type holding 14 rounds of 3-inch ammunition and the other type 20 rounds of 75-millimeter ammunition. These chests are removed from the trucks and stores at the firing point. You have been sent lists of the fire-control equipment, and corrected lists will be again sent. It is proposed to supply the heavier caliber guns such as the proposed 4.7-inch, which are for army artillery, in accordance with table of organization 208, series C, although following modifications of this table will apparently be necessary. (1) Addition of one reconnaissance car. (2) Use of 10-ton artillery tractor instead of ammunition truck for towing gun, due to increased weight of heavier caliber, which will be mounted on caterpillar trailer. (3) Use of 6 ammunition trucks for ammunition and personnel. When the 75-millimeter and 3-inch matériel are used for army artillery it is recommended that for uniformity of matériel organization the 3-gun battery organization govern shipment. It is thought that if the same matériel is organized in the 2 and 3 gun batteries great confusion will result, and therefore shipment from here should be made on the 3-gun basis for all existing matériel. Suggest in service 1 gun be considered in reserve. Further information follows by courier. It is requested that the present tables of organization for anti-aircraft matériel be thoroughly reviewed in consultation with Lieut Col. Capron, as it appears they have to date not received adequate attention.

On November 4 (X–249–7):

Reference S–331, paragraph 1D. Status of range tables request is as follows: The following tables are ready for the printer and will be shipped early in December: 75-millimeter gun anti-aircraft; 75-millimeter gun equipment for anti-aircraft, model 1916; 3-inch anti-aircraft gun, model 1917.

On November 9 (X–268–8):

Reference S–330, paragraph 2F, regarding production of 3-inch anti-aircraft auto-trailer mounts and 75–millimeter anti-aircraft truck mounts. Refer to X–235, paragraph 9, regarding 75-millimeter anti-aircraft truck mounts. The production of the 3-inch anti-aircraft auto-trailer mount units is still being delayed, due to machining of recoil valve, which is not yet entirely satisfactory. Experiments on this valve are being expedited, but until satisfactory valve adjustment is determined, production of these units will not be definite. None will be floated this month. This will cancel promises given in X–56, paragraph 1C. Expect to be able to advise you definitely regarding delivery in about two weeks. Production is proceeding on the mounts and about 25 are now on the

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assembling floor which can be completed shortly if valve adjustment is determined, and several hundred are in process of machining.

On November 9 American Expeditionary Forces cabled (S–431–1–H):

Reference trailer carriage anti-aircraft gun, model 1917, request you provide shields placed directly on both sides of guns to protect the gun layer from the detrimental disturbing local blasts and noise occasioned by the rapid rate of firing. Also desirable that traversing handwheel be of greater diameter. Production should not be delayed to effect these changes.

On November 14 Ordnance cabled (X–271):

The following tabulation gives the status of shipment overseas of principal items as of November 1 and floatings in October: 75-millimeter anti-aircraft guns, model 1916, released 15, freighted 14, docked 2, floated 4; auto-truck mounted, model 1917, released 15, freighted 14, docked 2, floated 4; truck, White, for 75-millimeter anti-aircraft mounts, released 15, freighted 14, docked 2, floated 4; shrapnel, 75 millimeter anti-aircraft, released 30,000, freighted none, docked 251,271, floated 21,879.

On November 16 American Expeditionary Forces cabled (S–455–1):

Ordnance status as of November 1. Artillery listed thus: Items; total received in France; received on European orders since October 15; new orders accepted in Europe since October 15. Promised deliveries by numbers and months: 75-millimeter anti-aircraft guns; 72 complete matériels; 11 guns only; rest none.

On November 22, Ordnance cabled (X–314):

Following figures submitted in order to assist you and to suspend or reduce future ordnance shipments as quickly as possible. The figures are from a report dated November 15: 3-inch gun and caisson, anti-aircraft trailer, ordered 50, freighted 200, docked none, floated 50.

On November 29 (X–323–5):

Reference your 505, paragraph 2B, recommend improvised anti-aircraft mounts be scrapped.

On December 8, American Expeditionary Forces cabled (S–581–2–A):

Ordnance status as of December 1. Artillery listed thus: Items; total received in France; received on European orders since November 1; all artillery orders being canceled. All deliveries suspended, so promises not stated: 75-millimeter anti-aircraft complete units; 72, none. Three-inch Stokes trench mortars; 1,657; 442. Six-inch Newton trench mortars; 559; none.

On December 17, Ordnance cabled (X–383–5):

Eight crates containing 8 75-millimeter anti-aircraft truck mounts on order US–927–R–042 loaded and shipped in error on steamer *Point Lobos* December 12. Request shipment be returned to United States consigned to Commanding Officer, Coast Defenses, Eastern New York, Fort Totten, N. Y.

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ANTI-AIRCRAFT MACHINE GUNS.

The following cablegrams dealt specifically with the use of machine guns for anti-aircraft service:

On June 13 Pershing cabled (1297–3–B):

Item, 500 anti-aircraft Marlin machine guns should be shipped with all additions you state. These are essentially Marlin tank guns and carriages. (2) Items badly transmitted should read, "25 up to 50 short tons." In accordance with the suggestion in paragraph 2, your cablegram 482, have substituted 52 Fords for 32 machine-gun trucks of standard types, and have (3) figured our requirements will be on this basis.

On June 16 (1316–4–B):

With reference to paragraph 1, your cablegram 1435, and paragraph 1, my cablegram 1169. 500 anti-aircraft Marlin machine guns should be shipped with all additions. You state these are essentially Marlin tamping guns. (2) Items badly transmitted. Should read "Pyrotechnics of 250 short tons"; Item, "220 Fords substituted for Marlin gun trucks." In accordance with suggestion in paragraph 2, your cablegram 482, have substituted 52 Fords for 32 machine-gun trucks of standard type, and have figured our requirements on this basis.

On June 24, Ordnance cabled (1595–1–C):

Arrangements being made for modifying Marlin machine guns for anti-aircraft purposes. Production schedule will be furnished later.

On June 28, Pershing cabled (1389–2):

Five hundred Marlin anti-aircraft machine guns are for protection of depot and dump. Requisition 361. Ship in space allotted to automatic arms in July 200 and obtain for August priority 300 guns. Post mounts entirely satisfactory for Marlin anti-aircraft machine guns. Special feed drums for high angle fire should be shipped with guns.

On July 13 (1457–1–M):

With reference to paragraph 1D, your cablegram 1536. Browning heavy and Browning light machine guns considered most suitable type for anti-aircraft work. Use of Browning heavy for this purpose should not take precedence over arming of machine-gun battalions and replacement guns. An adjustable high tripod is desired. Drawings have been forwarded you of types developed here. Transportation question being investigated.

On August 18, American Expeditionary Forces cabled (21–5–B):

Advise definitely seaboard deliveries Marlin, Browning, and Vickers anti-aircraft guns with mount and sights. Situation serious in First Army. Schedule not being met. Urgent that production be increased.

On October 29, Pershing cabled (1849–10) (*corrected mail copy*):

This cable outlines the present plans for utilizing available anti-aircraft machine-gun material and will shortly be followed by a written report. Sub. A. Mounts for machine-gun companies, reference S–23, paragraph 2, and X–28.

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paragraph 3A. Anti-aircraft adapters required for Browning tripods but not necessary for model 1918. Production should be scheduled accordingly. For anti-aircraft battalions. Reference A–2006, paragraph 10. Omnibus tripods with special adapters will be furnished here. For all artillery except railroads high tripods similar to designs previously forwarded. For balloon and searchlight companies the Cygnet wheel mounts, reference X–64, paragraph 1G, can be used. Quantity mentioned sufficient to meet the requirements. Mounts for searchlight companies should be arranged for Lewis guns and for balloon companies for Hotchkiss guns unless Lewis for this purpose can be furnished from United States. Can this be done? No Cygnet wheel mounts required for Vickers or Browning guns. For dump and fixed-defense work, post mounts with high tripod head. Sub. B. It is not believed that any further work should be done on pedestal or trailer mounts other than the completion of present orders for Cygnet wheel mounts, as there is no apparent use for this type beyond that specified for searchlights and balloons. Sub. C. Sights: Reference A–1688, paragraph 1A. All P. B. corrector sights now available in United States should be shipped immediately. How many are available and when will orders be completed? Work should be pushed on forward Area and Peycru sights for Hotchkiss and Browning guns. For rifle company with Browning automatic rifles and machine-gun company forward Area sights should be provided at rate of one to every four guns. For anti-aircraft battalions, artillery, searchlights, and balloon companies and fixed-defense work, P. B. corrector sights should be supplied at rate of one per gun until such time as Peycru sights are available. Sub. D. Gun: At present the Hotchkiss gun is standard for all anti-aircraft work excepting searchlights, for which Lewis guns should be provided at rate of two per light. Balloon companies should also be provided with Lewis guns at rate of 18 per section, if possible; 500 Marlin guns will be modified for anti-aircraft work, but will not be available for some time. Sub. E. Accessories: A pintle and the necessary clamps for attaching should be provided at rate of one per gun for mounting the head of high tripods on artillery caissons during movement of batteries. All belt-fed guns should have belt feed drums or similar devices for moving belts with guns. Stocks should be provided for all guns.

On November 2, American Expeditionary Forces cabled (S–396–1):

Reference X–206, paragraph 1B, and S–300, paragraph 2D. Four 40-round magazines loaded with one-third tracer and two-thirds service ammunition and carried in Musette originally designed for caliber .30 Chauchat magazines are recommended for anti-aircraft work. Can these Musettes be furnished? Sub. A. Browning rifles to be issued for anti-aircraft work as follows: Four per infantry rifle company, including pioneer infantry; eight per battery of field artillery; and one per balloon company. Requirements of all material should be figured on this basis. Sub. B. Sixty pounds too heavy for mount for Browning rifles with infantry companies. Design of light folding stand similar to British mount for Lewis gun should be continued, but data insufficient now to recommend definite type of anti-aircraft mount for Browning rifle with infantry companies. This question will be discussed as completely as possible in report by courier at early date. Sub. C. Forward Area sight as designed by your office satisfactory and production should be rushed. When can these be supplied for Browning guns and rifles and Vickers guns?

As an indication of conditions, reference is made to the following cablegram, which was prepared by the American Expeditionary

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Forces, but was not sent on account of orders stopping shipment of matériel to France:

Reference X–267, paragraph 11. When cable S–23, paragraph 2, was sent, machine-gun tripod, model of 1918, had not been tested on this side for anti-aircraft firing. Test showed adapters not necessary for this tripod as reported in cable P–1849, paragraph 10A. [illegible] accordingly. Reference P–1849, paragraph 10–D. Hotchkiss adapters for high tripods and post mount should be given preference over other types. At the present time the Hotchkiss gun is the only one in use for anti-aircraft firing with the single exception of Lewis guns on the projectors of searchlights, and all instruction work is being conducted accordingly. Latest tactical employment of anti-aircraft machine-gun battalions renders use of high tripods and post mounts impractical, as these battalions must be prepared to use ground fire as well as anti-aircraft fire. Equipment suggested in letter of September 4, OCOO ES 472.5/22, would be too cumbersome to transport, hence recommendations in P–1849, paragraph 10A. Print of adapter to be furnished this side went forward with complete written report on November 7; 100 are on order here. For Artillery and post mounts see cable S–431, paragraph 1–E; 500 post mounts and 500 high tripods were ordered here, but steps are now being taken to cancel this order. When P–1849, paragraph 10B, was written, little information was available here regarding Sechler trailers. The equipment must be such that both guns of each battery can be fired from the ground. Relative to caisson mountings the present practice is to fasten tripod head to caisson so that gunner can walk behind gun and fire during movement of battery. Impossible to state without test if the trailers with mountings attached will meet conditions. Recommend that only such of your present orders as are near completion be continued. X–206, paragraph 1B, was answered by S–396, paragraphs 1, 1A, 1B, and 1C. Trench sights, British type, for Browning automatic rifles should be provided as per paragraph 1A. Other quantities mentioned are sufficient. For number of 40-round magazines per Browning rifle, see S–396, paragraphs 1 and 1A. Following material should be furnished for balloon and searchlight companies: For each balloon company, 6 Cygnet wheel mounts; 6 Lewis guns; 6 Peycru sights; 1 trench sight, British type, for Browning automatic rifle; four 40-round magazines for Browning rifle; and 1 Musette, caliber .30, Chauchat type. For each searchlight company, 13 lights, 13 Cygnet wheel mounts, 26 Lewis guns, and 13 Peycru sights. Mounts for guns on projectors have been taken care of here and armament for all balloon and searchlight companies provided. In view of present military program these articles need not be shipped.

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Chapter VIII.

RESPONSE TO QUESTIONNAIRE.

On December 24, 1918, a report was submitted by the liaison ordnance officer, anti-aircraft artillery, American Expeditionary Forces, to the Office of the Chief Ordnance Officer, American Expeditionary Forces, for the attention of Field Artillery and Anti-aircraft Section of the Engineering Division, on a questionnaire which had been submitted to some 19 field officers of the Anti-aircraft Service, and this included field data, criticisms, and suggestions.[1]

This report states that the answers to the questionnaire represent the best opinions of field officers who have had the handling of the various types of French and American anti-aircraft artillery during the present war, and in it is expressed the thought that because of aircraft development future wars will require anti-aircraft artillery in quantities equal to field artillery.

As this report is based upon actual combat experience, a considerable number of abstracts are reproduced.

"The records of the only two French 75-millimeter anti-aircraft auto mounts owned by the United States while manned by Battery B, First Anti-aircraft Battalion, now the Twenty-third Battery, is 9 planes in 5,092 shots, or 1 plane for every 566 shots, and the combined records of the Fifth, Twenty-second, Twenty-third, Twenty-seventh, and Twenty-eighth Anti-aircraft Batteries is 17 planes in 10,273 shots, or 1 plane for every 605 shots. While these records are in excess of any known, it should be kept clearly in mind that a plane turned back, although unhit, is in effect defeated."

"The tendency to measure anti-aircraft artillery by the actual hits and not by the work accomplished is responsible for the present opinions held by some, that anti-aircraft is a weak branch of our service."

"The first blow of a foreign enemy attempting an invasion of the United States or its possessions would very probably be by the air."

"Any reasonable attempt at future preparedness, therefore, depends on the careful development and construction in very large quantities of a standard anti-aircraft mount, and only by standardization will this be possible at a low unit cost."

"No one type of anti-aircraft gun carriage or mount will ever satisfy all conditions of modern warfare. It is, however, possible and desirable to design and build a standard gun and top carriage having a wide range of action and by means of interchangeable base rings to use this gun on either a truck mount, a two or four wheel trailer, a caterpillar tread trailer, or as a semifixed mount, as each of these types has its own sphere of action."

[1] See report prepared by Capt. E. K. Standish, in collaboration with Capt. R. L. Goetzenberger, of Ordnance Department, on file in Technical Staff Library.

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"GUN."

"Should be 3-inch bore and have the maximum attainable practical velocity. While a larger bore is in many ways desirable, the necessity of great mobility and the loss in rapidity of loading a heavier shell, especially at high angles of fire, effects this. Dead time saved more than compensates for the reduced time of flight. In anti-aircraft firing it is generally the first few shots that count, the enemy plane then either getting out of range or changing his course frequently, therefore rapid and accurate service is essential."

"The ease of recoil is an important factor in the stability of the mount. The mount to be usable must be sufficiently stable so that the sights will continually remain on the target. The 75-millimeter French auto mount can fire 100 rounds on average ground without releveling, without the use of spades, and without throwing the sights off the target."

"If the drop-block type of breech mechanism is used the handle should be changed to give easier operation at high elevations. The rotating type of breech mechanism is preferable for high-angle fire. The firing pin should have a chain or rod connection, as the leather lanyard continually breaks in service."

"For use against aircraft, high-explosive shells only are wanted of high ballistic efficiency and of one standard interchangeable type."

"All officers interviewed were of the opinion that shrapnel should not be furnished at all."

"A single standardization time fuze should be furnished to give accurate ignition at all fuze-setter ranges from 500 meters to 14,000 meters, the latter figure allowing for any future increase in range, as maneuvering by the plane at higher altitudes must be anticipated. It is thought a mechanical or clockwork fuze can be satisfactorily developed for this purpose and standardized."

"Star shells interchangeable as to fuze should be furnished in the proportion of one for every four standard high-explosive shells."

"The 75-millimeter French anti-aircraft auto-cannon modified to allow maintaining the sight on the target while giving deflections to the gun, as in the French trailer mounts and with a few other very slight improvements has the practically universal approval of the officers interviewed. Considerable criticism was expressed of the Ordnance Department for its failure to build this mount at the start from the French drawings furnished." (Reference is made to this point in a memorandum submitted in January, 1919, by Col. J. B. Rose to the Artillery Division, from which is quoted: "It shall be noted, however, that at the date in question, July, 1917, the possibility of constructing French recuperators in this country was still entirely unsettled. It was necessary, therefore, to develop our own designs."

"The gun should have a depression of minus 5° and an elevation of plus 85°, and should have complete movement in azimuth. Actual firing records of the two auto mounts show that 90 per cent of all firing was at less than 30° elevation and that 50 per cent of this 90 per cent was at less than 20° elevation."

"Shields should be provided in front, above, and on the side of the gun pointer and deflection setter to keep out the noise as much as possible. It was found that at times telephones were useless, and orders had to be shouted and relayed by word of mouth to the guns."

"An attempt should be made to provide a simple but limited leveling device for the top carriage irrespective of the mount, with levels attached. In designing this leveling device its depth, as affecting the height of the top carriage, should be within 1½ inches. One minute should be the maximum time required to level the carriage."

"An additional interchangeable base ring mounted directly on the platform for the auto or the trailer mount; on a wooden, steel, or concrete ring, for the

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semifixed mount; or on an auxiliary circular pedestal for a four-wheel or caterpillar tread trailer; fitted with stops if required for the auto mount, would allow all of the top carriage, including leveling device, traversing, and elevating mechanism, and gun and recoil, as well as instruments, to be standardized."

"Every effort should be made to cut weight by improved design and by use of stronger materials, but without sacrificing stability and strength."

"The carriage should be designed for night lights."

"The stability of the carriage must be absolute. The American 75-millimeter truck mount and American 3-inch trailer as at present designed have not the necessary stability. This feature should be corrected on the 3-inch trailer by a different type of outrigger."

"INSTRUMENTS."

"All anti-aircraft artillery units should be fully equipped with modern instruments so that either the angle of approach or the tachymetric method may be used at any time."

"An instrument whereby the battery commander's station can secure and deliver to the gun crew firing data, thus eliminating several instruments from the gun carriage, has been devised but never used under battle conditions by American batteries. This instrument, called the corrector R. A., can be used for direct or indirect fire. With direct fire, a telescope on the gun follows the target, and from the corrector R. A., information given to the gun layers, is the vertical deflection correction, the lateral deflection correction, and the future fuze-setter range to target. The vertical and lateral deflection corrections are set off on the gun by the use of mil scales.

"The future fuze-setter range being given from the corrector, R. A., the turning of the fuze-setter range dial beneath a pointer moved radially across its face as the gun is inclined, allows the automatic setting of the superelevation. For indirect fire the corrector R. A. gives the gun the future azimuth and future angle of sight to target, and these are laid off on the mil scales of the gun. It also gives future fuze-setter range.

"At present greater accuracy and quicker action can be secured by direct fire. If efficiency can be secured by this method, it is preferable as delicate instruments are removed from the gun, and one instrument will often answer for a battery."

"Actual battle practice shows that it was necessary to allow 8 seconds dead time and fire every 4 seconds. Accurate firing could not be secured at greater speed than 15 shots per minute."

"In the 75-millimeter French auto cannon were furnished with Puteaux altimeter, tachyscope, angle of approach telescope, wind drum, horizontal telemeter, Brocq double-sight corrector, gun telemeter, and fuze-setter range dial."

"In the 75-millimeter French trailer mount the sights can be held on the target while the gun is offset, and this method should be adopted."

"The tachymetric method of fire control was used for approximately 85 per cent of the shots fired from the two 75-millimeter French auto cannon mounts."

"All anti-aircraft personnel should be equipped with gas masks having specially large glasses and constructed so that talking is easy. The American box respirator is unsatisfactory."

"A searchlight with each battery would be of great assistance. It should be under the control of the battery commander. A 150-centimeter light with hand control throughout and with open mirror has been designed for transportation and operation on a Cadillac chassis and weighs no more than the former 90-centimeter light."

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"A machine gun with high-angle tripod should also be furnished with each unit."

"In any war of movement the question of mobility of the artillery is of great importance."

"The automount is thought best for all front-line work."

"Trenches, shell holes, mud or soft ground, bridges down, light pontoons, location of guns known to the enemy, the necessity of repeatedly changing front, and for considerable distances, the relocation of ammunition dumps, camps, etc., all make it necessary that anti-aircraft artillery be extremely mobile.

"This means exceptional design to eliminate weight. It means that the pressure per square inch on the ground should be very low and at the same time the permissible speed of travel should be high."

"It has been necessary during a night to move anti-aircraft artillery 30 miles over muddy and broken roads to be emplaced ready for firing at daylight."

"The 75-millimeter French anti-aircraft auto mount has a speed of over 30 miles per hour on a fair road, can be leveled ready to fire in four minutes, and is extremely stable."

"The design of an auto mount should closely follow that of the French 75 millimeter, improvements being attempted to secure complete azimuth by changing shape of chassis and by increasing the ground-bearing surface, the construction allowing the use of a standard interchangeble base ring with simple locking means for holding the top carriage."

"Plenty of space should be provided for tools, extra tires, gasoline and oil, and spare parts. It is recommended that the semifixed mount be supplanted by a trailer with four separate short caterpillar treads and carrying a steel platform on which would be mounted an auxiliary circular base, at the top of which would be the interchangeable base ring for the standard top carriage. This platform should be low, with folding extensible side platforms, and be equipped with beam outriggers carrying jacks to give extreme stability without the use of spades."

"The trailer mount should have heavy brakes, steering mechanism, seats, mud guards, springs, axle snap hooks, spare parts and tool chests, and with standard trailer couplings and hooks for hauling by horses."

"A standarized 3-inch auto mount for front-line work and a standardized caterpillar tread trailer for the rear areas, having the same top carriage and gun, if properly designed, should cover most of the anti-aircraft work."

"Above all, the design of these two mounts should be started immediately."

"75-MILLIMETER FRENCH AUTO CANNON MOUNT."

"The following is a summary of the reports received from the officers who have handled this mount in the field."

"Two mounts, type FZ, and two caissons, type G. O., have been at the front for five months and are now owned by the United States. The guns are No. 15935 and No. 14225, tube No. 3382 and No. 2612, recoil mechanism No. 198 and No. 199, carriage No. 208 and No. 209; total rounds fired, 3,880 and 4,500."

"These guns were manned by the Battery B, First Anti-aircraft Artillery, now the Twenty-third Battery, First Battalion."

"Firing was between 3.50 a. m. and 9.30 p. m. No night firing by this battery because of lack of personnel."

"Other French autocannon batteries were manned by American personnel, alternating with the French. The French furnished 50 per cent high explosive and 50 per cent shrapnel. High-explosive 24/31 maximum horizontal range 9,000 meters."

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"The French have since made high-explosive 24/31 a maximum horizontal range of 9,000 meters, known as type A. Shrapnel was used only because of insufficient range of high explosive furnished."

"Ammunition furnished was very accurate. Battery B had a total of about 25 misfires out of 8,380 shots. These misfires were attributed to primers set too far down in reloaded shells, 17 occurring in one morning."

"Very few shells were stuck in gun. Shells should be cleaned and tried before time of using and a coat of lard oil or graphite put on the rotating band."

"When stuck, the shells are removed by a rammer with hollow head, so that the blow comes on the ogive and not on the fuze. The loader and firer should have a careful training with dummy shells of the same weight as the standard. Shells are often stuck by too rapid movement of the breech block."

"Battery B had the rear end of one caisson shot away. Repaired at mobile ordnance repair shop in two days."

"The gun firing-pin spring frequently breaks and the breech-locking device was broken four times in the latch. It was thought that this was caused by wear. Extras could be carried and changes made in three minutes."

"In operating the breech mechanism the right hand was used to open and close the breech and the lanyard was pulled with the left hand. The leather lanyard frequently broke where it passed through the eye, and a very short lanyard was necessary."

"Very little trouble was experienced from coppering. The guns were cleaned with cold water, dried, and greased after every 100 rounds or less, and also every morning and night. At night a coating of heavy grease was put on and removed in the morning. Grease and oil are a good protection against the effects of gas."

"All gears, roller paths, and moving parts should be dust proof. Shells landing near guns have often put them out of action until they could be cleaned."

"The carriage can be put in readiness to fire in about four minutes and ready to move in about three minutes. At Le Bruil, southwest of Dorman, the guns were located by German artillery and were moved out under fire in two minutes. Heavy rains also frequently make it necessary to move the guns."

"The guns can be depressed to —3 inches and elevated to +70°."

"The trailer mount, in the opinion of the officers experienced in its use, is superior to the truck in the following points: It has complete movement in azimuth. Its breech is higher from the ground and therefore easier to load. It is possible to give the gun deflection without throwing the sights off the target."

"The truck mount is admittedly superior as to mobility, and traction must be furnished the trailer which can not be traveled at much greater than 8 miles per hour because of the effects, very detrimental, of jolting and bouncing. It was hauled by a Latil tractor."

"More men and their equipment can be transported on the autocannon mount. The trailer mount has greater road pressure per square inch."

"The trailer mount is satisfactory as to stability, the four large spades aiding greatly, although it is thought the ground pads should be larger."

"The trailer mount requires about 15 minutes to get in position as against 4 minutes for the auto mount, and about 20 minutes to get out as against 3 minutes for the auto mount."

"The spades occasionally break when locked for travel, and the forgings should be strengthened. The spades do not greatly interfere with loading."

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"The gun elevation is from 0° to 73°."

"It is recommended that anti-aircraft artillery for defense of rear areas, such as ammunition dumps, aircraft or balloon hangars, be designed to set above ground without the necessity of digging pits. It generally required a week or more to emplace a semifixed mount."

"Defense at Colombey-les-Belles, sector No. 10, consisted of six American and two French semifixed mounts. Two American semifixed were mounted as designed by the Ordnance Department, in pits with 2 by 4 cribbing, the other four being mounted on a wooden octagonal frame, 6 feet 6 inches from ground to top of the base ring, the platform being suspended in the standard manner. (Photographs of this mount are attached.) Maj. R. R. Robertson, who set these, states that it requires two weeks' average time to mount one gun in pit, and if frames were cut and bored for bolts, the above ground mount can be completed in one day. The French 75 millimeter can be put in pit in four days. The American mount takes longer than the French, because of extra depth and because of piling which must be leveled on top for base ring."

"The lack of head room on American mount makes it necessary that the loader and firer stand on a lower platform, and as constructed they are in an extremely dangerous position. The changed American semifixed frames were never received at the front."

"The maximum depression was 10° and maximum elevation 78°, which is not sufficient."

"The guns at Colombey-les-Belles were mounted in three groups, Group A having four guns about 150 feet apart, Group B and Group C having two guns each. The battery commander's station was about midway and slightly back of most likely line of fire. The Ordnance Department station was generally about 2 miles away with telephone connection."

"The four-gun groups did most of the firing. On October 30 planes came down Nancy Road and dropped 22 bombs east, west, and north to field, but none nearer than 1 kilometer, making three trips from 6 p. m. to 10.30 p. m. Battalion A fired 537 shots; Battalion C, 60 shots. On October 28 a single large plane dropped 7 bombs at 6 p. m., doing no damage. Battalion A fired 34 shots and Battalion C fired 21 shots. On October 18, at noon, Battalion C fired 26 shots at two Fokker planes."

"Both the American and French semifixed mounts are very crude and hardly satisfactory for the accurate work required of anti-aircraft artillery. The American mount is difficult to serve and to emplace, and it is recommended that no more be made. Insufficient space is provided for personnel. Three men were sent to the hospital with broken ear drums, and the heat from explosions sometimes singed their hair. The space for the gun loader and the firer is cramped and dangerous, and the deflection setter has to work in an awkward position. No ladders were provided for the men to reach their position. The American mount is too heavy. Eight men can mount the French piece in one-half day, and 12 men need one and one-half days to mount the American piece. The traversing required 2 men."

"This mount consists of a standard 75-millimeter French gun and recoil mechanism fastened securely to a steel frame carrying two sets of trunnions and steel trail. One set of trunnions is for road travel of the gun and frame on detachable wheels. When mounted the other set of trunnions rests in bearings carried by side frames fastened to a V-shaped platform, which can be split in the middle for transportation and erection. The gun and recoil mechanism being fastened to the trail, elevation is given by a cable fastened to the trail and carried over a drum with a counterbalancing weight on the opposite side and a handle on the drum to give elevation. Traversing is secured by a cable

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and hook, which by vertical shaft and worm and gear pulls the platform around on rollers running on top of circular steel ring."

"The French 75-millimeter has 0° depression and 82° elevation, but when mounted in pit was not fired below 18°."

"One gun mounted near Soppe-la-Maut was struck by a German shell, thought to be 155-millimeter, and completely wrecked, and in one case a round of 30/55 shrapnel tore and cracked the tube at the muzzle end of the gun, the shell going on. Exact cause is not known, but thought possibly caused by steel in rotating band. Shell did not burst. Abnormal recoil was noted."

"Gun at Manonville had fired 7,000 rounds and was still apparently in good condition."

"French furnished shell with special rotating band of steel color, possibly graphite, which was used to clean copper, 21 shots being fired in one case French also had a solution which was fairly satisfactory for removing copper."

"The breech threaded sectors sometimes caused trouble by chipping, particularly if breechblock was loose. Firing pins occasionally break."

"One recoil mechanism was smashed by direct hit and one had to be sent to repair shop because of excessive leakage at piston end. Occasionally a gun failed to return to battery, thought to be caused by overcompression of air. The gun was returned by removing plug."

"Screw filler was satisfactory."

"The traversing rollers often slip when the rail is wet or muddy and the rails get out of line. The roller-path key works loose. The carriage jumps about one-half inch on firing at high elevations. The American mount does not do this."

"HEADQUARTERS ANTI-AIRCRAFT SERVICE,
"AMERICAN EXPEDITIONARY FORCES,
"*December 3, 1918.*

"Memorandum for Chief of Artillery, American Expeditionary Forces.

"The number of troops in the Anti-aircraft Service at the time of the armistice was about 12,000. Comparatively few of these were on the front, but the results actually obtained by those that were on the front are so remarkable and unprecedented that it is recommended that they be published in commendatory orders by the commander in chief. The following outline is suggested:

"The results obtained by the American Anti-aircraft Service with our armies from July 17, 1918, at Chateau-Thierry up to the time of the armistice are so remarkable as to warrant publication.

"The results of these batteries which brought down one or more planes during this period are as follows:

"Average number of shots per plane, 605. The average number of shots per plane for all anti-aircraft batteries serving in our army area during this period, including those batteries sent for instruction, is 1,003. These results far surpass all expectations, one plane for 8,000 shots being heretofore considered good average. Machine-gun records are as follows:

Organization.	Number of shots fired.	Planes brough down.
Fifth Anti-aircraft Battery	520	1
Twenty-second Anti-aircraft Battery	2,116	2
Twenty-third Anti-aircraft Battery	5,092	9
Twenty-seventh Anti-aircraft Battery	1,028	3
Twenty-eighth Anti-aircraft Battery	1,517	2
Total	10,273	17

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First Anti-aircraft Machine Gun Battalion.

Organization.	Dates.	Planes brought down.
Company A, First Anti-aircraft Machine Gun Battalion	Sept. 6–Nov. 11	2
Company B, First Anti-aircraft Machine Gun Battalion	do	5
Company C, First Anti-aircraft Machine Gun Battalion	do	9
Company D, First Anti aircraft Machine Gun Battalion	do	8
Company A, Second Anti-aircraft Machine Gun Battalion	do	5
Company B, Second Anti-aircraft Machine Gun Battalion	do	4
Company C, Second Anti-aircraft Machine Gun Battalion	do	7
Company D, Second Anti-aircraft Machine Gun Battalion	do	1
Total		41

"Total number of shots fired by anti-aircraft machine-gun companies during periods stated, 225,115.

"Average number of shots per plane, 5,500.

"A comparison of the number of planes brought down by all anti-aircraft machine guns on our army front warrants a conclusion of relative efficiency of about 300 to 1 in favor of those of the Anti-aircraft Service.

"Anti-aircraft machine-gun troops and anti-aircraft searchlight troops have carried on their work with an aggressiveness and with results which are phenominal and unprecedented.

"The following specific instances are of special interest:

"At Chercry, October 13, 1918, eight Fokkers were chasing one American plane back to our lines; Battery A, Second Anti-aircraft Battalion, First Lieut. T. J. Bell, Coast Artillery Corps, commanding, brought down two of these enemy planes.

"At Jaulny, November 5, 1918, five Fokkers were returning from destroying an American balloon; the First Platoon of Company B, First Anti-aircraft Machine Gun Battalion, First Lieut J. C. Mickle, Infantry, commanding, brought down two of these enemy planes.

"At Esnes, October 29, 1918, the Twentieth Anti-aircraft Searchlight Platoon of Company A, Fifty-sixth Engineers, Second Lieut. H. R. Davis, Corps of Engineers, commanding, brought down an enemy plane with machine guns.

"JAY F. HOPKINS,
"*Colonel, Coast Artillery Corps,*
"*Chief, Anti-aircraft Service.*"

"MEMORANDUM FOR INTERALLIED ANTI-AIRCRAFT COUNCIL.

"12 DECEMBER, 1918.

"ANTI-AIRCRAFT MATÉRIEL.

"*Guns.*—Caliber: Gun's caliber to be as large as rapidity of loading will permit. Rapidity of loading can not be sacrificed because the loss in dead time in loading would more than compensate for gain in reduction of time of flight.

"*Velocity.*—Velocity should be very high. A few hundred rounds of ammunition cost no more than a gun tube. Tubes should be supplied so that they can be expended freely. The gain in efficiency will more than compensate for this policy.

"*Projectile.*—Should be of high ballistic efficiency, filled with high explosive, and provided with a time fuze, probably clockwork, which must be reasonably accurate.

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"*Mount.*—All-around fire and as mobile as possible.

"*Pom-poms.*—Probably of larger caliber than any now designed in order that the projectile may contain a reliable fuze. Its mount to be all-around fire and sufficiently mobile to insure its keeping up with infantry.

"*Machine guns.*—To be of larger caliber than at present in order to obtain increased range. Bullets in proportion, one tracer, one armor-piercing, and three ordinary is satisfactory at present.

"*Searchlight.*—150-centimeter searchlight, with hand control throughout and with open mirror, has been designed which can be transported and operated on our Cadillac chassis. It is scarcely heavier than the former 90-centimeter light, and very satisfactory.

"JAY F. HOPKINS,
"*Colonel, Coast Artillery Corps, Chief Anti-Aircraft Service,*
"*American Expeditionary Forces.*"

"HEADQUARTERS ANTI-AIRCRAFT SERVICE,
"FIRST ARMY, AMERICAN EXPEDITIONARY FORCES,
"*19 December, 1918.*

"Memorandum for Design Section, Chief Ordnance Officer, American Expeditionary Forces, Paris.

"The following French anti-aircraft matériel has been in use under my direction and observation:

"(*a*) 75-millimeter cannon on semifixed carriage.

"(*b*) 105-millimeter cannon on semifixed carriage.

"(*c*) 75-millimeter cannon on auto mount.

"(*d*) 75-millimeter cannon on trailer mount.

"The semifixed carriage should not be depended upon for any way of movement, though it can be used for defense of fixed sensitive areas; one great argument for its being so employed being its cheapness.

"The auto mount has proved more mobile than the trailer with present methods of traction, and for shifting from one part of the front to another quickly, will continue the better for work of that nature.

"The mobility of both auto mounts and trailers was reduced by bad roads, and this condition will probably always be met in any war of movement anywhere, and especially in the United States.

"The difficulty may be at least partially met by furnishing caterpillar traction for the trailers, but this will not insure the passage of the trailer, as at present designed, over all the bad places that will be encountered.

"It is reported that the Germans made considerable use of the horse-drawn matériel.

"Another difficulty for the heavy anti-aircraft guns is the passage of temporary bridges (including pontoons).

"The present matériel (French) is good, but the anti-aircraft artillery needs a mobile gun of greater range and shorter time of flight, the carriage should be able to stand traction over rough roads and soft roads, and if necessity arises, off the roads.

"All anti-aircraft artillery should be able to use indirect fire whenever it is desired to do so.

"If an accurate, self-contained range finder can be developed, it should be provided; until it is found, accurate instruments for use with base line of about 500 meters (1,000 meters at the outside) should be furnished.

"R. W. COLLINS,
"*Colonel, Coast Artillery Corps.*"

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"HEADQUARTERS ANTI-AIRCRAFT SERVICE,
"AMERICAN EXPEDITIONARY FORCES, FRANCE,
"21 December, 1918.

"A. *Mobile mounts.*—(1) Zero degrees minimum angle of elevation. In recent firing from 70 to 80 per cent of firing was below 25°. (2) Eighty-five or preferably 90° maximum angle of elevation. All dead angles should be avoided if possible. (3) Balance: The gun should be so balanced that it can be easily elevated and depressed, and so that it can be traversed without great effort by pushing on the carriage, the latter effected, possibly, by a disengaging clutch between the traversing-gear train and the carriage. (4) No horizontal dead angle. Mobile mounts are liable to be used in fixed defenses where the field of fire is not predetermined. (5) Separate control for laying in elevation and azimuth. (6) Absolute mobility. The gun should be capable of being brought from the road to the firing position, and conversely, in a minimum of time. Spades and extra trusses above the number on the French automount (four jacks and two buttresses) defeat this end. (7) A compound elevating mechanism for the gun whereby the superelevation movement will not affect the movement of the vertical sight, as in the case of the French autotrailer mounts. (8) The setting mechanism for all instruments and scales should be so arranged that the movements may be continuous, easy, and smooth. A small handwheel, instead of the knobs at present on the 1917 model auto mount, United States, would probably accomplish this purpose, (9) Semiautomatic or full-automatic breechblock. (10) Seats for the manning detail that have sides and backs. The seats on the present auto mount, United States, are impractical.

"B. *Semifixed mounts.*—1, 2, 3, 4, 5, 6, 7, 8, 9, 10, ditto. (11) The mount, whatever its design, should be so arranged that it can be jacked onto the running gear and moved from place to place intact, as in the case of the British Mark IV pedestal mount. In case of emergency, such a mount can be easily moved overland to the point of emergency.

"*It is recommended.*—(1) That a common gun, from base ring up, be designed for all types of mounts. (2) That this gun be of high muzzle velocity—2,400–3,000 foot-seconds. (3) That all guns be equipped to fire with both angle of approach and tachymetric methods of fire control. (4) That shrapnel be abolished from anti-aircraft artillery. (5) That the value of the laminated explosive shell (as the Italian), the phosphorus shell, tracer shell, and the illuminating shell be determined by experiment. (6) That a light caterpillar tractor mount be attempted.

"BENJAMIN F. HARMON,
"Captain, Coast Artillery Corps."

From another overseas report on "Anti-aircraft Artillery Matériel" the following abstracts are taken:

"Much of the advance so far has evented because of a knowledge of the capabilities and limitations of modern optical, mechanical, and electrical instruments. An even more specialized knowledge of these matters is essential for future progress.

"With the design of more powerful guns, naturally, is embraced that of a fuze capable of withstanding all of the detrimental effects of gunfire under every condition. The mechanical fuze appears to be the only logical solution."

"The best protection against airplanes flying below an altitude of 2,500 and a range within 4,000 meters is the pom-pom, a 1 or 2 pounder gun firing at the rate of about 120 rounds per minute. No gun of this type has been success-

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fully designed and constructed. The necessity of using ammunition having a supersensitive fuze with back time protection adds to the problem of gun design. Machine guns of larger caliber, if possible, at least with increased range, should fulfill effectively the requirements within a zone of action of altitude 1,500 and range 2,500 meters."

"Because of the important field played by aerial sound-detecting apparatus, searchlights, and telephony, including wireless, any future progress in the design of anti-aircraft artillery matériel should not be undertaken before having a complete knowledge of these subjects. With the perfection of airplane motors and their interconnected functioning apparatus, the design of aircraft, and the art of flying, other factors upon which the design of artillery equipment should likewise be based, enter into the problem. A thorough coordination of all these details is absolutely necessary."

"Anti-aircraft gunnery differs from other forms of gunnery, such as field-artillery problems. It is a new subject, one more complicated than any other artillery problem, and consequently one which essentially demands new methods and modes of measurement."

"Its rôle is only beginning. It is hardly possible to estimate how great will be the future importance of the perfection of the country's aerial defense from a strategic point of view. The value of every advance made during the war is therefore more than doubled, for it will be of permanent value in time to come. Aviation as an offensive arm will remain the principal arm. Anti-aircraft artillery, as a defense branch, will play opposite it the part that coast artillery plays to the naval squadrons of the seas. An arm which will continue to increase with the progress of aviation."

It will be observed that in the responses to the questionnaire no mention is made of corrector V. C., as described on pages 31 and 32, and it may be that the field officers generally had not had opportunity to familiarize themselves with this fire-control development.

Star shells are mentioned on page 69, and possibly there is opportunity for more elaborate development in this connection, for assistance during night attack, by perfecting an illuminating element of great intensity, long burning, and which would be sustained aloft for a lengthy period by parachute or other device, and which could be projected from an anti-aircraft gun.

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Chapter IX.

SUMMARY.

Any attempt to summarize the history of anti-aircraft guns, with more in mind than a simple summarization of matériel produced, must take into account a number of viewpoints.

It must be recalled that the whole subject of anti-aircraft gunnery is limited to the present European war, and that material progress in what might be termed the science of anti-aircraft gunnery was largely limited to the last year of the war.

At the beginning there were no established principles, no matériel, no organization, and such progress as was made was made under stress and entirely as the result of conditions developed in actual combat. Those who carried on their labors at a distance from the zone of action were dependent upon those within the active zone for a statement of needs and an outline of the most promising method of development.

It seems very probable that the information in the hands of many of those outside of the zone of action was far from being up to date and that the mental picture of the actual process, as involved in the physical handling of equipment which brought forth the best results, was not always clear. Certain it is that the knowledge of what was being accomplished from week to week was confined to comparatively few.

As an example of the impression that might be conveyed to those who obtained their impression solely from figures, it is unnecessary to go further than the American Expeditionary Forces' weekly statement of the artillery situation as of record November 16, 1918, five days after the signing of the armistice, as issued from the office of the Chief Ordnance Officer, American Expeditionary Forces, Requirements Division. A copy of the figures from this report, which would seemingly convey information as to the total amount of anti-aircraft artillery, both from United States sources and from the French, which was in the hands of the American forces at the time of the signing of the armistice is reproduced below:

Type of matériel.	From—	Quantity ordered.	Total delivered in France.	In reserve.		Total with troops.	
				With troops.	Service of Supply.	Advance area.	Train area.
3-inch anti-aircraft guns	United States	612	0	0	0	0	0
75-millimeter anti-aircraft truck mounts.	do	51	18	0	17	2	59
75-millimeter anti-aircraft improvised mounts.	do	50	50				
75-millimeter anti-aircraft mounts	France	4	4				
75-millimeter anti-aircraft guns	do	66	66	0	23	2	59
Do	United States	65	18				

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An inspection of this tabulation would lead one to believe that the only anti-aircraft artillery, from any source, in the combat of the American troops, consisted of two 75-millimeter anti-aircraft truck mounts and two improvised mounts fitted with French 75-millimeter field guns, or four units in all, distributed among three American armies. The "Statement of anti-aircraft situation" dated October 12, 1918, as included in the confidential report of October 10, 1918, from Chief Ordnance Officer, American Expeditionary Forces, to Chief of Ordnance, Washington, "Review of United States Artillery Program," showed "a great shortage of anti-aircraft matériel," but there was more protection and more opportunity to judge by American troops in the handling of anti-aircraft guns than these tabular figures might lead one to believe.

These figures are doubtless correct as a matter of statistical record, but it is known that two type FZ 75-millimeter French auto cannon were at the front for five months, in the hands of Battery B, First Anti-aircraft Artillery, now known as the Twenty-third Battery, First Battalion, and that other French auto cannon batteries were manned by American personnel, alternating with the French, and that at Colombey-les-Belles, sector No. 10, there were six American and two French semifixed mounts.

The number of troops in the Anti-aircraft Service at the time of the armistice was about 12,000, and although comparatively few of these were at the front, the following organizations are referred to as those which actually brought down enemy planes:

Fifth Anti-aircraft Battery.
Twenty-second Anti-aircraft Battery.
Twenty-third Anti-aircraft Battery.
Twenty-seventh Anti-aircraft Battery.
Twenty-eighth Anti-aircraft Battery.

The anti-aircraft machine-gun organizations which are listed as having brought down planes are:

Company A, First Anti-aircraft Machine Gun Battalion.
Company B, First Anti-aircraft Machine Gun Battalion.
Company C, First Anti-aircraft Machine Gun Battalion.
Company D, First Anti-aircraft Machine Gun Battalion.
Company A, Second Anti-aircraft Machine Gun Battalion.
Company B, Second Anti-aircraft Machine Gun Battalion.
Company C, Second Anti-aircraft Machine Gun Battalion.
Company D, Second Anti-aircraft Machine Gun Battalion.

It is also of record that the American troops handling anti-aircraft guns obtained remarkably good and constantly improving results.

As to what was accomplished in the furnishing of anti-aircraft artillery matériel prior to the signing of the armistice, the figures of the United States production are not imposing, but it is well to

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bear in mind that all things are judged by comparison. The United States entered the war on April 6, 1917, and by November 11, 1918, it had completed 50 anti-aircraft improvised mounts for 75-millimeter guns, forty 75-millimeter anti-aircraft truck mounts, ninety 3-inch high-powered anti-aircraft guns and mounts of the seacoast type, five of which had been mounted on auto trucks, and one 3-inch anti-aircraft gun and trailer, model 1918. About 300 of these latter were in the course of construction, with many of the parts well along.

The French entered the war in August, 1914, and the status of production of French anti-aircraft mounts is given in courier communication, dated October 24, 1918, as follows:

75-millimeter auto-trailer type	38
75-millimeter auto-cannon type	160
75-millimeter platform mount	600
105-millimeter platform mount	150

(Ninety of these 150 platform mounts were equipped with 75-millimeter guns in lieu of the nonreceipt of a sufficient number of 105-millimeter cannon, for which the platform was originally designed.)

No data are at hand as to the quantities of anti-aircraft matériel which the British had with their troops at the front, although it is known that they had some 3-inch pedestal mounts and some 13-pounder motor lorries. On page 27 reference was made to the fact that the first of their 3.6-inch anti-aircraft caterpillar trailer mounts, which had just been completed, was inspected at Woolwich Arsenal on November 8, 1918.

Figures are not available with which to make any intelligent comparison of machine-gun equipment as applied to Anti-aircraft Service.

A new arm of the service has been initiated, and the brief experience of the present war furnishes overwhelming evidence of the necessity for its elaborate development.

It is apparent that the information of greatest value in connection with anti-aircraft weapons and accompanying equipment must come from those who have had actual experience in Europe. The opinions of a number of such officers are set forth in the preceding pages. It would undoubtedly be of value to supplement this information with verbal conferences with these or other officers on their return to the United States. Attempt has been made to locate such officers, but without success at this time.

As stated on page 44, Chief Ordnance Officer, American Expeditionary Forces, held the opinion on November 7, 1918, that "* * * this branch of warfare may still be considered to be in its infancy * * *."

On page 68 mention is made of the expressed thought from American Expeditionary Forces sources that "* * * future wars will

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require anti-aircraft artillery in quantities equal to field artillery * * *."

Gen. Pershing's report of November 20, 1918, to the Secretary of War, published as an appendix to the Secretary's annual report, made no mention whatever of anti-aircraft artillery or machine-gun activities. On the other hand, the memorandum of December 3, 1918, from the Chief of Anti-aircraft Service to the Chief of Artillery, American Expeditionary Forces, as quoted on pages 74 and 75, indicated the opinion that much progress had been made. This report stated that the total of 58 planes officially recorded to the credit of Anti-aircraft Service in this communication were all brought down between July 17, 1918, and the signing of the armistice on November 11, 1918, or within a period of less than four months. It does not state what was accomplished prior to this period, nor is there any indication of the number of enemy planes which were deterred from their objectives or which may have been disabled without official count.

The figures of record of Military Aeronautics as to the number of enemy planes brought down by American aviators during the entire war are: Confirmed, 491; unconfirmed, 354. Confirmed means that the actual bringing down of the planes must have been observed by some one from the ground. Unconfirmed means that the bringing down of the enemy plane was reported by the aviator, but was not witnessed by some one on the ground. Without in any way attempting an official comparison between the results obtained by American aviators, as compared with anti-aircraft guns in the hands of American troops, but more with the idea of indicating that substantial progress was being made by the latter, the following details are brought to light: Comparing the confirmed figures only, in the two cases, we find that for the total 19 months of the United States participation in the war, the average monthly number of enemy planes brought down by American aviators was slightly less than 26, or 103 for a total of 4 months. Obviously, it is not a fair comparison to deduce from these figures that the anti-aircraft guns were eventually bringing down one-half as many enemy planes as were being brought down by the aviators, for the latter's average per month was probably higher during the last 4 months of the war, but just what this latter average was is not at present apparent. It seems worth while, however, to present these figures, as the impression seems to prevail that very little was accomplished by the anti-aircraft gunners, and in view of the crudeness of much of the matériel with which they were obliged to operate, and the fact that they were firing from a fixed position upon a rapidly moving target, while the aviator was firing from a position more or less parallel to a moving target, it will be observed that a proper amount of credit should not be withheld

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from the men operating the anti-aircraft guns. If two automobiles were running at 100 miles an hour in a parallel line on a smooth sand beach, there would be no more difficulty in ranging one automobile from the other than there would be if both automobiles were stationary. This is not, of course, a true comparison of the relative movement of two airplanes under combat conditions, but is important that we gain a clear conception of the difficulties under which the anti-aircraft gunner labored in ranging his objective and the very brief space of time during which the objective was in range of his projectile in order that we may visualize the extent of his accomplishments, and deduce that from the progress made he has won the right to much better developed matériel with which to operate and to have large quantities of this matériel placed at his disposal.

On page 55 of the History of 75-millimeter Field Gun Program reference is made to the appointment of a board of officers to convene in France for the purpose of studying armament and types of artillery matériel to be assigned to a field army. This study will probably include anti-aircraft matériel, but no specific and comprehensive plans have been encountered for the study and coordination of all activities, including artillery, machine guns, ammunition, searchlights, sound-detecting apparatus, fire control, wireless telephony, organization, scope and development in connection with all forms of anti-aircraft service. It will be apparent that this would include measures for offense, defense, and assistance to friendly aircraft and has a distinct bearing upon the activities undertaken under the head of Military Aeronautics and possibly Naval Aeronautics. Anti-aircraft matériel, as distinct from aircraft armament, has been handled not only by anti-aircraft battalions and Coast Artillery Corps, but has been used or recommended for use by practically every branch of the service, including Cavalry.

On page 41 reference is made to the need for telescopes or high-powered field glasses to distinguish between friendly and enemy aircraft without loss of time, and a photograph is attached which shows the aircraft markings of the different nations, which will direct attention to this phase of the subject.

Mention has been made of variations in the flight of a projectile with gun at high elevation, due to variation in atmospheric density and in windages at various altitudes, but no mention has been made of obtaining data concerning these variations, as they change from day to day. One method employed was to plumb the atmosphere from the bottom up by permitting a balloon to rise and noting its speed and change of course. The speed of ascension would be affected by changes in atmospheric density and by side pressures due to windage, and these features were duly noted and plotted.

Mention has been made of the desirability of more effective protection for friendly observation balloons from the attack of enemy

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airplanes, and for this the "pom-pom" has been suggested. In conversation with an overseas officer he made the statement that he had seen four of our observation balloons brought down inside of 10 minutes.

Reference has been made to the use by the enemy of "flaming onions" for the protection of their own observation balloons and of their deterrent effect upon our own aviators.

While operations during the time of war were carried on under stress, nevertheless development at such time took place under conditions which it is impossible to reproduce with the same effectiveness in time of peace. Page 44 refers to difficulties encountered in the provision of suitable target conditions for training purposes.

A brief reference is here made to the general routine of aircraft activities during the European war.

Enemy Zeppelins and bombing planes provided a means for attack upon England against which its mighty fleet provided no protection. On page 28 reference is made to the new branch of service which was built up to to meet this emergency. The part played by small incendiary projectiles is referred to on page 33. The thought may arise as to whether aerial incendiarism will be further developed by the shell discharge of long streamers of flaming material which would catch upon the wings of airplanes or otherwise act effectively, or to any possible use of quick acting gas, or of shell discharge of gas or liquid which would produce a large burst or shower of flame for the disabling of aircraft operators. At present we have no device corresponding with the "flaming onions," which disconcerted our airmen in attacks on enemy balloons.

As far away as the United States is from the scene of the European war, it will be recalled that provision was made against aircraft attack, even at a time when the sea was free from enemy ships, and the danger from enemy aircraft attack in the United States could apparently be brought about only by the release of aircraft from submarines, unless the thought was entertained at that time that it was in the range of possibility for aircraft to cross the ocean. At the present time this possibility seems quite probable.

Attention must be given to possibilities attached to use of helium or other light noninflammable gases, in connection with lighter-than-air machines.

On the battle front in Europe the customary practice was to establish the observation balloon beds about 7 kilometers behind the front lines and each morning to tow the balloons by motor-driven winches mounted on motor trucks to a distance about 5 kilometers behind the front lines and to hold them there through the day unless attacked. The winch trailer carried six machine guns and their crews, and on arriving at forward station, these machine gunners distributed

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themselves in favorable position in the vicinity of the winch, for the protection of the balloon and the winch against enemy airplanes. The balloon was usually set at an altitude of 4,000 to 4,500 meters, depending upon the atmospheric conditions, and if attacked by airplanes, was drawn down until the balloon was at a height which would bring the enemy airplanes within range of the machine gunners. The official record of planes brought down by these machine gunners is four, and it is understood that the total actually disabled was considerably greater. Pom-pom fire has been suggested as a better protection for observation balloons.

On page 43 reference is made to the descent by parachute of observation balloon men, and their views concerning the use of automatic rifles from the balloon basket, in the event of the balloon being attacked by airplanes. In the event of enemy gunfire from the ground, the balloon was towed out of range by means of the motor truck which can tow at the rate of about 10 miles per hour.

Attention is called to the vulnerability, not only of the balloon, but of the motor-winch truck, and also of the balloon beds or filling stations, which are subject to airplane attack or map firing from field artillery. Regarding the latter condition it will be remembered that as the balloon beds are 7 kilometers behind the lines and the enemy artillery would be a considerable distance behind their own lines, enemy field artillery attack upon balloon beds can be attempted only by long-range guns. This is in a measure true of similar attacks upon observation balloons, and the winch trucks when in their customary position of 5 kilometers behind friendly lines, although they are sometimes inadvertently gotten closer to a front-line position. It is understood that on the British front observation balloons were subject to enemy fire from guns of as large a caliber as 155 millimeters, using explosive shell with clockwork fuze, which provided for the necessary range; but no concentrated attack of this nature has been reported on the American front.

It will be held in mind that for reasons indicated on page 18 it is intended to operate against aircraft back of the enemy lines as well as against enemy aircraft over friendly territory. This means long-range guns to reach observation balloons or airplanes operating behind enemy lines in positions which permit of their occupants observing and reporting on conditions inside friendly lines.

The general operations of the enemy aircraft and of our aircraft are, to some extent, similar, and a description has been given of the manner in which our own observation balloons are handled. A brief outline of the methods of operation of our own airplanes may assist in visualizing the opportunity for attack upon and defense against enemy airplanes, with the use of anti-aircraft guns, as well as the possibility of assistance to our own airplanes.

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In general, airplane routine is divided into pursuit, observation, and bombing.

Pursuit planes as a rule are one-man planes, of light and speedy type, equipped with fixed machine-gun armament. These are planes which operate singly or in groups, in regular patrol, or in response to alarms and in which the individual acts largely upon his own initiative in judging the opportunity and method of attack upon enemy aircraft, and in the evolutions performed either in operation against enemy aircraft or in his own defense. The altitude at which the pursuit plane flies largely depends upon the objective of the moment, but on the Marne his patrol work was done at about 3,000 meters, in the Argonne at about 600 meters, and around Toul at from 3,000 to 6,000 meters' altitude. He is, therefore, subject to all kinds of enemy fire, both from the air and from the ground.

He is constantly hunting for trouble, and frequently our own anti-aircraft artillery helps him to find it. From the air it is difficult for one pilot to discern an enemy airplane at any considerable distance, and when he notes the explosion of shells from our own anti-aircraft artillery his attention is called to the presence in that vicinity of enemy aircraft, and he immediately directs his flight to the scene of the aerial burst of these shells. This will make clear the necessity for high-powered telescopes or field glasses in the hands of our own anti-aircraft men, to provide against their firing upon friendly airplanes when they approach to take a hand in the attack upon enemy planes. This will also bring out the need for effective liaison between our own searchlight men and our own airplanes, in connection with night attacks by the enemy. If our searchlight men can pick up an enemy airplane over our lines, they can hold their light upon him, and in some cases so blind him as to cause him to lose his sense of location, while in the meantime a friendly plane may keep without the focus of the searchlight and maneuver into a position favorable to attack. From the ground we are able to discern the proximity of an airplane through the noise of its engine, but the enemy airplane pilot is prevented from hearing the noise of another airplane through the noise of his own engines.

The observation plane usually carries two men—a pilot and an observer—and is somewhat slower than the pursuit plane. It has the fixed machine-gun armament at the disposal of the pilot and, in general, flies at its "ceiling," or the maximum height to which the plane is adapted, save when on some direct objective. In good weather, clear photographs may be obtained from a height of 5,000 meters, and the average photograph is taken at about 3,500 meters. This plane is therefore, in the main, subject to ground attack from enemy artillery only and not from machine guns, and it does not maneuver and dodge about to the extent of the pursuit plane, as it

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has a definite accomplishment to perform, such as map making and other observation of the disposition of enemy location, formation, and transportation.

It has, however, other definite duties, such as trench observation, artillery regulation, and infantry contact, which again holds it to a more or less definite course, but does subject it to machine-gun fire. The artillery regulating consists of flying over the enemy lines and observing objectives or the nearness of arrival of friendly shells to these objectives, for the purpose of checking or correcting field artillery fire. Infantry contact consists of the following up of our own infantry during attack and reporting back to our own artillery the exact position of friendly infantry during an advance, to provide for the proper regulation of friendly artillery fire as well as for the information of infantry maneuvering headquarters.

Bombing planes are large and heavy and carry two or more men. Their operations are carried on either by day or by night; they fly in a fixed formation—usually in the form of a triangle, with the apex leading—and, as a rule, proceed with one objective and a prompt return, following release of bombs over that objective. The pilot has at his disposal fixed machine guns, shooting directly forward, and other machine guns—usually double Lewis—are provided for operation by another man, in any direction which will clear his own plane. Bombing formations usually fly high and do not maneuver, as they depend for their protection against enemy airplane upon their fixed guns for protection straight ahead and upon their free mounted guns and large volume of fire for protection in other directions, or upon the protection of accompanying pursuit planes.

It will be seen then that the anti-aircraft gunner's activity may include either artillery or machine-gun fire against the pursuit plane or the observation plane, but is confined to artillery against the bombing plane. It will further be observed that anti-aircraft machine-gun fire with its stream line of projectiles, including its fire-correcting tracer bullets, is the most effective against quick-acting planes which are free to maneuver and are constantly changing both course and altitude, provided the altitude and distance bring the plane within the machine gun's range. The called-for development of the larger-caliber machine gun would increase this effective range and the provision of an artillery shell with a wider range of burst than the present, or of an artillery projectile which would release "flaming onions" or irregularly moving, wide area covering disconcerting elements, would permit of anti-aircraft guns giving increased assistance in this field.

Against bombing planes artillery alone is effective, and as these fly at increasing altitudes, increasing range from anti-aircraft artillery has proved necessary. They, together with dirigible balloons,

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being of large carrying capacity, involve the greatest physical destructive menace from the air, and as they fly in formation and usually along a definite course and at a more or less maintained altitude, they form a more promising target for the anti-aircraft artillery, which is slower in maneuver than the anti-aircraft machine gun.

A higher-speed projectile is desirable both on account of accomplishing increased range and the decrease in error due to variables, through the reduction of the time of flight. The wider area of burst is more desirable for the purpose of increasing the effectiveness through shock or fragmentation, and the mechanical fuze is essential to the elimination of previously mentioned fuze difficulties. Noise of burst is also desirable, as well as smoke and, to some extent, incendiary effect, although an airplane is usually set on fire only by puncturing its petrol tank.

The psychological side of anti-aircraft fire seems to be worthy of considerable attention, for while the reduction of enemy personnel or of the enemy aircraft is the primal object, the experience of our own aviators makes it very evident that noise or flaming objects have a decidedly deterrent effect. even when the known record of physical damage through certain agencies is small. In conversation with the ordnance liaison officer attached to Military Aeronautics, he stated that during his stay in France, and his close association with the first pursuit group, consisting of 84 planes, and extending over a period of eight months, he knew of only one American flyer whose plane had been destroyed by enemy anti-aircraft fire, and of one other flyer whose engine had been damaged by an enemy shell, which had failed to explode, but who was able to land within friendly lines. Questioned as to the statistics regarding casualties among observation and bombing planes, he was unable to find definite records.

This brings out the point that pursuit flyers were offered steel seats and also steel sides to protect them from machine-gun fire and apparently it was left optional with them as to whether they wished to accept this protection with its handicap of additional weight.

There were, of course, many flyers brought down, but they were brought down by enemy aircraft and apparently not to any large extent by enemy anti-aircraft fire. It likewise seems clear that the enemy anti-aircraft fire had a very decidedly deterrent effect and from several sources indications have been given of the deterrent effect of the enemy "flaming onions."

In view of the above, the record of enemy planes actually brought down by American anti-aircraft fire, as referred to in official communication quoted on pages 74 and 75, is the more worthy of attention.

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Chapter X.

ADDITIONAL NOTES.

FRENCH 105-MILLIMETER ANTI-AIRCRAFT TRAILER MOUNT.

In an appended report from American Expeditionary Forces, dated February 28, 1919, there appears a description of the above matériel, but this description is confined largely to the fire control in connection with the apparatus.

The fundamental characteristics of the 105-millimeter Schneider matériel is described as being the suppression of the laying by direct sighting on the objectives and the putting in operation of semiautomatic telepointing, which requires only relatively simple mechanisms not likely to require readjustment.

One of the advantages noted with reference to the employment of this indirect firing is the elimination of the danger of confusing objectives.

As has been previously stated, this matériel is so arranged that it is fired from a platform resting on the ground, when in battery, but capable of being rapidly put on wheels by means of jackscrews, which likewise facilitate its being put into battery.

The breech mechanism is automatic and is effected by the action of a special recuperator functioning upon the return of the gun into battery. The breech of the eccentric screw model assists in ramming the projectile home. The ammunition is placed on a revolving loading tray equipped with a mechanical device for fuze setting.

FRENCH SIGHTING AND FIRE-CONTROL EQUIPMENT.

Appendix 16 and Appendix 19 from American Expeditionary Forces, and dated February 1, 1919, describe in detail the mechanical or electrical construction of anti-aircraft fire-control and sighting apparatus, and the text is accompanied by numerous illustrations.

GERMAN ANTI-AIRCRAFT ARTILLERY.

In Appendix Report 15 from American Expeditionary Forces, dated February 20, 1919, is contained a compilation of information on enemy equipment, which compilation is believed to cover all types of matériel employed by the Germans during the entire period of the war.

Attention is first devoted to the fire control. For fire in still air, the values for the different corrections of the moment were given by

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tables in function of the mean temperature of the powder, and the weight of a liter of air on the ground, at the battery position.

It is a matter worthy of note that for the permanent corrections of fire, the Germans distinguish between a new gun and a worn gun. The Germans reason that the influence of wear of the tube is of the same nature as the influence of a variation in the temperature of the powder; that is, a variation in muzzle velocity.

(REMARK.—The fact that the Germans make their ballistic corrections by merely changing the distance by a constant quantity with the resulting obligation of accepting certain theoretical inaccuracies in order not to complicate the giving of orders is obviously the consequence of their having neither fuze setter nor corrector.)

Further note is made that it does not appear that the Germans have developed to any extent study of wind corrections.

In the German instruments, no instrument seems to exist for measuring velocity; the same being estimated according to the type of airplane, and probably with an allowance for the wind.

Apparently the angle of the route is estimated either by the operator of the telemeter, or by the officer commanding the fire, and called out at intervals of 30°, relative to the figures on the dial of a watch. For instance, an airplane "Going 0" is indicated as 12, an airplane "Coming 60" is indicated as 4.

The shell used is principally high explosive. Shrapnel is only exceptionally employed and never for ranges beyond 4,000 meters.

The fire is conducted by zones; the regulation is about 100 meters; the dimensions of the zone swept and the direction in which it is swept depends upon the number of guns, the number of rounds per gun, and the route of the airplane. The Germans consider only a coming plane, a going plane, and a crossing plane. In the first case the fire is regressive; in the second and third instances it is progressive. The number of rounds to be fired by each gun depends upon its rapidity of firing and loading, and the danger apprehended from the objective. Fire is opened at the following commands: "Number of rounds, progressive or regressive, range, vertical deflection correction, lateral deflection correction, fire!"

The Germans do not make any range adjustment. They employed no distant observers. From the first rounds are estimated the lateral and vertical deflection corrections. German batteries fire three rounds and then wait to observe the three bursts before continuing the fire.

Photographs of instruments and blue-print diagrams to illustrate the text description of fire control methods are included in the report.

The principal matériel of the German anti-aircraft artillery may be classified as follows:

Light.—Sections of two pieces, 37-millimeter guns, either a revolving gun or the automatic type, horse drawn.

Semifixed.—Sections or batteries of naval 77-millimeter or 88-millimeter guns; also 90-millimeter guns.

Automobiles.—77-millimeter automobile gun (isolated singly or in section).

Trailer.—80-millimeter and 88-millimeter guns (battery of two guns).

Horse drawn.—This is comprised of a certain number of emergency equipments used only occasionally against aircraft. French 75-millimeters transformed, 77-millimeter Schnetzler carriage, model 1914, and 100-millimeter guns.

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In addition, the Russian gun of 76.2 millimeters on pedestal mount (battery of three or four guns), concerning which is given a more detailed description, this gun being one of the best known and the most generally used in the German Army.

Light Mounts.

37-MILLIMETER REVOLVING CANNON.

The carriage is fixed on a wooden platform equipped for firing from legs or props. The rigid part of the mount consists of a cast-iron column on which the movable part can turn freely. The gun is composed of five barrels held together by two collars. The shells are placed in a slide and are successively forced into the tubes by means of a rammer, as the tubes are successively rotated into the proper position for the entrance of the shell. Each round is fired separately, and it is stated that a friction primer is employed. The empty cartridge case is ejected before the barrel it occupied again comes opposite the loading slide.

37-MILLIMETER AUTOMATIC CANNON.

This mount is supported by a carriage having two wheels, and a trail, and is fired from the mount. The gun is fundamentally a large Maxim machine gun. Range, 3,000 meters; weight of projectile, 0.460 kilogram. Two shell provided—one loaded with black powder, and the other a tracer shell, leaving a green trail.

Semifixed Mounts.

88-MILLIMETER GUN.

(Length, 45 calibers; muzzle velocity, 750 to 765 meters per second.) This is a German naval gun on a Krupp and Eberhardt pedestal mount. Range, 9,150 meters; weight of projectile, 9.60 kilograms; time fuze.

Different arrangements of platforms are shown. The general mount is composed of a framework of beams used as outriggers from a central bed on which is bolted a cast-iron circular plate. To this plate is bolted a stationary column on which the whole of the movable part turns. This mount is also used by the Germans as a trailer type, the entire unit above the circular bed plate being identical with that used with the semifixed mounts. The semifixed mounts themselves, together with the guns, are transported from place to place on motor trucks.

An accompanying photograph shows five rounds of ammunition packed in a steel drum or barrel, fitted with sleeves or diaphrams to receive them. These drums may be rolled, instead of being dragged or lifted, in moving short distances.

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Automobile Mounts.

77-millimeter gun.

No jacks are employed for putting it into battery; this is done by locking the springs.

The photograph which accompanies the report shows a flat-bodied truck with gun so mounted as to apparently permit of all-around fire. The front wheels of the truck have rubber tires and the rear wheels have double rubber tires, but a point worthy of note is that on both front and rear wheels there is a cleated rim extending beyond the rubber tires and at smaller diameter. During the passage of the machine over hard roads, the rubber tires only would come in contact with the road surface, while in mud or soft ground, not only would a wider wheel surface be presented to prevent the weight of the vehicle forcing the wheels deeply into the ground, but the cleats on the extension rims would provide traction between the wheel and the soft or slippery ground surface.

Trailer Mounts.

80-millimeter gun.

(Length, 45 calibers; muzzle velocity, 715 meters per second.)

The frame consists of channel-iron sections on which rests the platform supporting the gun. The placing in battery is accomplished by locking the springs and lowering two outriggers to insure lateral stability. The gun and recuperator cradle is trunnioned to the rear of the center of gravity of the combination, and equilibrating springs are located beneath the cradle at the center of gravity. The gun with its recoil mechanism is raised and lowered by means of a pinion and segment gear; a separate gear mechanism being supplied for superelevation. The cast mount has an all-around traverse on the channel-section frame; being adjusted by worm-screw mechanism.

The principal characteristics of the gun are:

Total length of tube	3.60 meters (45 calibers).
Total length of bore	3.38 meters (42 calibers).
Total length of rifling	2.78 meters (35 calibers).
Grooves:	
Number	24.
Angle	6° 10′.
Pitch	Constant.
Amplitude of elevating mechanism	70°.
Maximum range	13,000 meters.

The ammunition consists of a brass cartridge case with an explosive shell and a three-ring time fuze. The complete round weighs 12.265 kilograms. The explosive projectile is solid forged with two rotating bands, and with its fuze weighs 7.920 kilograms. The fuze,

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which is a time fuze only, may be graduated from 3 to 29 seconds. The fuze weighs 465 grams, and the threaded diameter of the fuze body is 50 millimeters. Attention is directed to the fact that German projectiles with a fuze hole threaded to the same diameter are found only in their naval artillery.

88-MILLIMETER GUN ON TRAILER MOUNT.

This matériel is similar to that of the German 88-millimeter semi-fixed mount. Its characteristics are:

Bore, 88 millimeters. Length, 13 feet.
Breechblock, horizontal sliding.
Elevation, 0° to 70°; azimuth 360°.
Circular base with auxiliary leveling pintle and screws at bottom.
Height from steel platform to trunnion, 55 inches.
Height from face breechblock to trunnion, 18 inches.
Length of cradle, 51 inches.
Height from top of platform to ground, 30 inches.
Frame, 10-inch channel; 18-inch wide folding platform extension each side.
Wheel base, 13 feet 8 inches; tread, 72 inches; wheels, 3 feet diameter, with two 4-inch steel shoes flexibly mounted on each rear wheel and one on each front wheel.
Double seat with steering wheel and brake at the front.
Four built-up steel T sections, 8 feet 6 inches long, are slipped, two on each side, under frame over rollers when in firing position. These tees carry 4-inch diameter screw jacks with 19-inch diameter plates with webs for support. An auxiliary screw is located at the top of these jacks.
Platform 6 feet wide extended by folding platforms to 9 feet wide between wheels, and is 38 inches wide between wheels at ends.
Traversing and elevating handwheels located on both sides.
Both ends have eye coupling and hooks for traces.
Above gun is a 6-inch diameter by 52-inch long recoil cylinder, and underneath is a 4-inch diameter one.
Double elevating racks are provided. On the left side and fastened to the trunnion is a pointer and scale giving elevation in degrees.
On the right side and fastened to the trunnion is the sighting apparatus bracket.
The traversing and elevating of this gun is very easy, the gun being well balanced. All parts are rugged in construction. A removable travel lock is provided so that the gun is transported on the road with muzzle to the front. Equilibrating spring is inside of pedestal.

HORSE-DRAWN MATÉRIEL.

FRENCH 75-MILLIMETER FIELD GUN.

Transformed and rebored to 77-millimeters. (Length, 35 calibers.)

Tube.—Only the part behind the breech housing is utilized. It is screwed on a tube of the same length as the 75-millimeter bored to 77-millimeters, reinforced by a steel sleeve of almost the same exterior dimensions as the bronze jacket of the 75-millimeter.

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For the recoil, the traversing rollers are replaced by the sliding blocks. The rear blocks are carried by the breech housing, the front and intermediate ones by special hoops. The rollers at the muzzle became unnecessary and therefore no longer exist.

Cradle.—The interior parts have been retained completely with the exception of the square bronze scale for which the chambered section of the brake has been modified by the addition of one plate of brass flanged and riveted.

The drum of independent sight has been adapted to the firing of the 77-millimeter and provided with an adjustable zero clinometer.

Rocker.—The length of the segment rack of the aiming cradle has been increased.

Carriage.—The trail of the 77-millimeter carriage has been cut to about one-third its length from the pintle end.

The part carrying the trail spade and the pintle is fixed at the extremity of the flask of a German howitzer trail. The whole constitutes the trail of the new carriage.

The part in front of the carriage of the 75-millimeter has been changed by omission of the axle, axle plates, and the parts constituting the road brake, all of which have been transferred to the flasks of the light howitzer. The rear part has been equipped with trunnions which permit angles of elevation on the howitzer carriage.

Counterbalance.—The counterbalancing of all oscillating parts, consisting of tube, cradle, carriage of 75 millimeter, and gun shield, is maintained by means of a strong helical counterpoise spring.

This mass, due to this counterbalancing, may be elevated and depressed with ease. The system can be placed in two fixed positions on the carriage of the howitzer. To lock it in each of these positions the cradle has been equipped with a front sector having two stops, into which a large steel latch engages. This sector latch is carried by the howitzer carriage and operated with ease from an eccentric crank shaft. The corresponding angles of fire are shown in the following table:

	Low position.		High position.	
	Maximum.	Minimum.	Maximum.	Minimum.
	° ′	° ′	° ′	° ′
First matériel	37 20	0 40	61 15	23 15
Second matériel	28 20	10 15	50 20	14 40

The 75-millimeter carriage set in field firing position, the apparatus functions as in the regulation 75-millimeter gun. The scale, the drum, the collimator, the graduation for the angles of site, and the lever perform their usual parts. A footboard fixed to the left flask

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of the carriage indicates that the pointer operates the sight in a standing position.

The 75-millimeter carriage set in anti-aircraft firing position, the pointing is direct and the pointer causes the cradle to follow all the vertical movements of the objective. In some cases, for anti-aircraft fire, the Germans had replaced the French collimator by a slightly different design of sight.

The wheels of the carriage are often set in a circular traversing track which is fixed either in concrete or securely held to the ground. The carriage is traversed in this track for large angular displacements and to the smaller movements by axial sliding, the amplitude of which is 72-millimeter.

The central transom of the howitzer carriage carries a movable shaft which is fastened by means of a bolt to the head of the pivot and transmits to the latter the reaction of the recoil.

The trail spade is supplied with a wooden shoe which gives to the rear of the carriage a strong point of support on the ground, and permits with facility lateral pointing in all azimuths.

The shield of the 75-millimeter also protects the pointing mechanism. On one of these mounts, the collimator has been placed about 60 centimeters back to the right by means of a special bracket.

Sight has remained independent, both for field and anti-aircraft fire. The dials, however, have been slightly modified.

The sight drum has three graduations: The first, F (probably Feld), bears the division 0 to 4,700; the second, L (probably Luft or Luftfahrzeug), also bears divisions 0 to 4,700 but apparently in different progression; the third, F and L, carries the divisions 4,500 to 6,700.

These graduations are probably used as follows:

(*a*) Graduation F, for field fire at low ranges.

(*b*) Graduation L, for anti-aircraft fire at low ranges.

(*c*) The mixed graduations for either, firing at high range.

In order to correct the trajectory deformation, the Germans have assembled a sight compensator which simultaneously moves the reference marks of the three graduations. The compensator handle is marked "higher" and "lower," and in each of these directions the compensator graduation runs from 0 to 10 (one division equals about one-fourth degree).

MODEL 1914, 100-MILLIMETER GUN.

(Length, 35 calibers.) Range, 11,050 meters; weight of projectile, 18 kilograms; time fuze.

This gun has not been especially designed for anti-aircraft service. It has no particularly interesting points except its pointing apparatus, which has already been described.

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CARRIAGE, SYSTEM SCHNETZLER, FOR ANTI-AIRCRAFT SERVICE WITH THE 96 N/A FIELD GUN.

This carriage is composed of two triangular wooden improvised frames joined by stay rods. Between these frames the gun, with its trail and wheels, moves on its trunnions.

The entire mount can turn through 360° around a vertical axis on a platform built up as follows: A central wheel buried just below the surface of the ground; a pentagonal traversing rack of wood, having a radius of 2.25 meters. Both are held in place by stakes. The central pivot is fastened in the hub of the wheel. The center transom of the carriage rests on this pivot. The frame rests at its outer extremity on the traversing rack by means of a single roller. The stability of the mount is secured by the two wheels, placed at the ends of the center transom, and running around the rim of the buried wheel. Two props prevent the mount from swinging forward when the gun is fired.

The weight of the trail is balanced by a spring counterpoise attached at the top to the fore part of the recoil cylinder and at the lower extremity to the front crossbar. Two stay rods fixed at one end to the pivot and at the other to each extremity of the cross member at rear of the carriage (improvised) insure the rigidity of the whole.

The gun carriage, resting in the axle bearings of the framework, is elevated and depressed by means of a cable rolling on a windlass and attached to the end of the trail. The windlass turns between two vertical planks placed to the rear of the carriage.

For road travel the improvised carriage rolls on its two wheels and is drawn behind the limber, the gun behind this carriage.

Pointing.—The roller, which rolls on the traversing rack, is rotated by means of a mechanism controlled by the handwheel placed to the left rear of the improvised carriage. Large displacements are given by means of the traversing handspike fixed to the rear of the frame. An azimuth scale is placed on the ground concentrically with the buried wheel. In front of it moves an azimuth index pointer fastened to the improvised carriage. The gun mechanism for elevation has been retained. Large displacements are given by the operation of the windlass, which is provided with a latch and ratchet wheel to secure in desired position.

POUTILOFF RUSSIAN 76.2-MILLIMETER GUN ON PEDESTAL.

This gun is one of those most frequently used in the Germany Army. It is a Russian field type, models 1900 and 1902, transformed with a special German pedestal.

In the construction of the unit, a rigid column carries the gun and recoil mechanism, which latter are trunnioned off center with respect to their center

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of gravity. The recoil mechanism is located below the gun and a rod attached to a point corresponding more or less with the center of gravity of the gun and recoil mechanism reaches down to a equilibrating spring located within the supporting column. This supporting column rests upon a platform to which is permanently attached one of five radial arms, and which permanently attached radial arm acts as a trail for a two-wheeled vehicle when the gun is jacked up to sufficient height to permit of the slipping on of two wheels to axle extensions which are attached to the platform. In firing position the platform is lowered to the ground and the other four radial arms are then attached to the central platform to provide a proper bracing. Each of the radial arms is held in place at its outer extremity by stakes driven into the ground through holes in the end of the arm, conveniently provided for that purpose. The support for the gun trunnions is rotated about the upper part of the rigid column by suitable mechanism which provides for all-around fire, and another mechanism which provides for a maximum elevation of 70°. Range, 9,400 meters; weight of projectile, 6.860 kilograms; time fuze.

MACHINE GUNS.

No specific technical data concerning the German 2-centimeter gun has been obtained, but it is known that such a gun was employed for anti-aircraft purposes. Its rate of fire was 2 per second, and its maximum range about 3,000 meters. The ammunition was a high-explosive shell with a supersensitive percussion fuze, interspersed with tracer shell.

WAR DEPARTMENT,
OFFICE OF CHIEF OF ORDNANCE,
Washington, D. C.

FORM 1941.
Ed. June 18—19—500.

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Chapter XI.

PHOTOGRAPHS.

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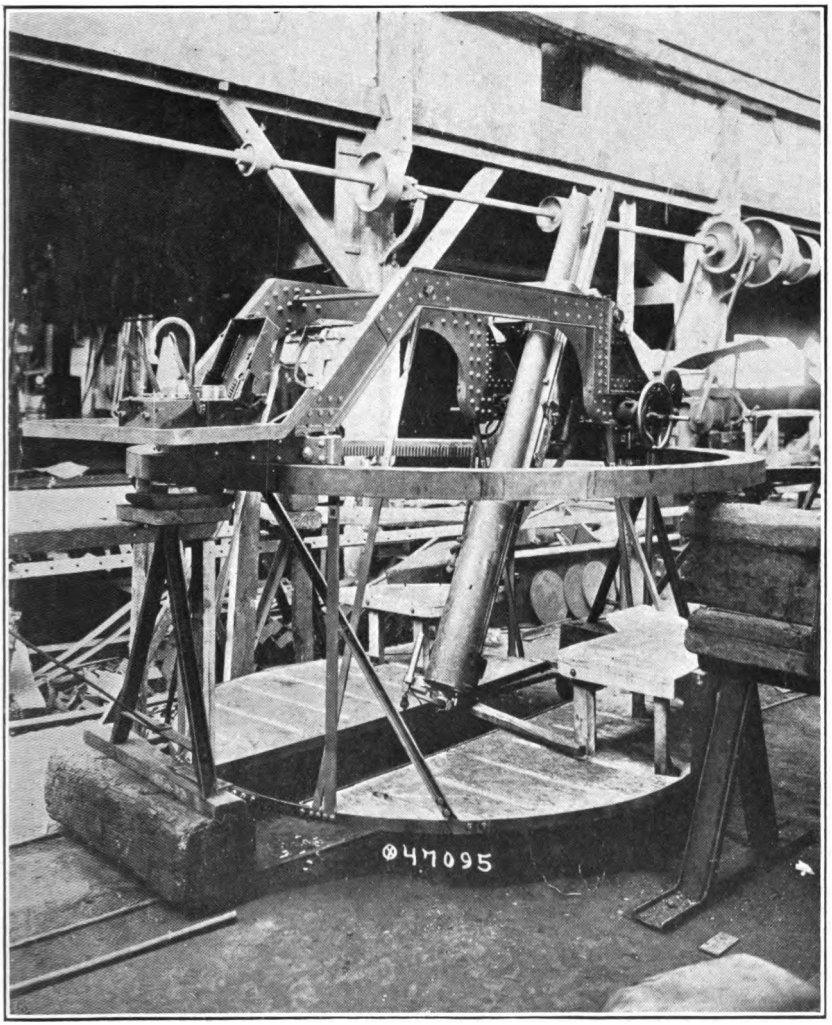

AMERICAN IMPROVISED ANTI-AIRCRAFT CARRIAGE.

Model of 1917, after it had been changed and equipped with 75-mm. French model 1897 field gun in French shop. Note changes in platform and change of horizontal supports to riveted U frame to provide better space for loading. (See p. 45.)

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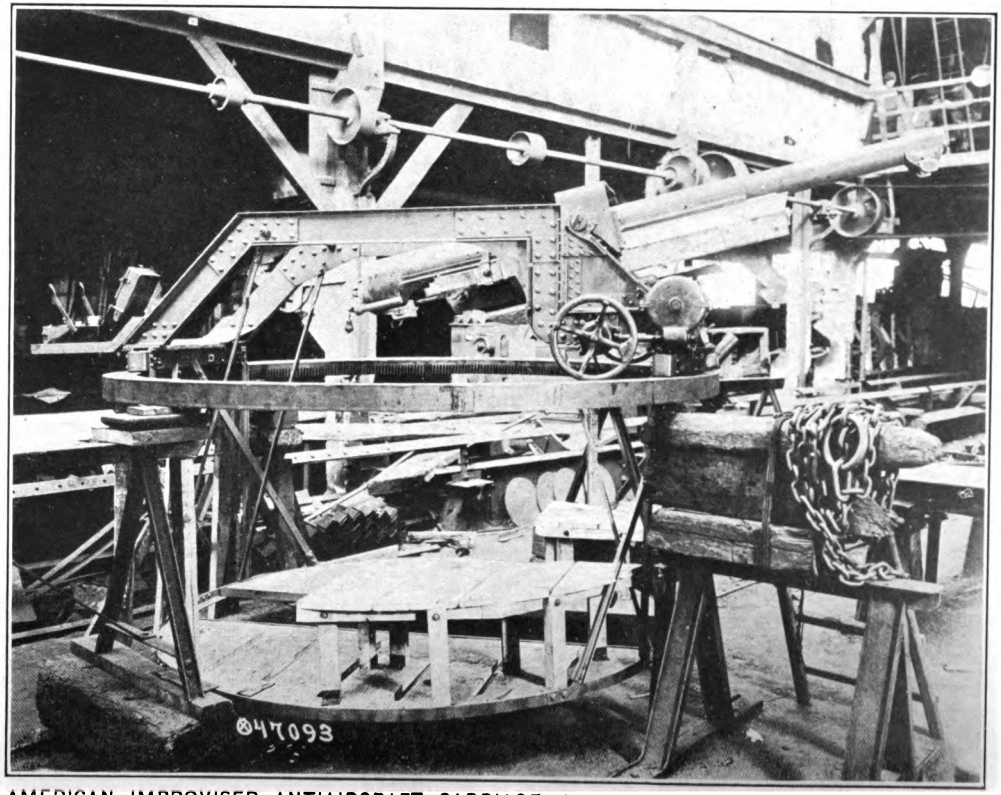

AMERICAN IMPROVISED ANTIAIRCRAFT CARRIAGE, MODEL OF 1917, AFTER IT HAD BEEN CHANGED AND EQUIPPED WITH 75-MM. FRENCH MODEL 1897 FIELD GUN IN FRENCH SHOP.

Note changes in platform and change in horizontal supports to riveted U frame to provide better space for loading. (See p. 45.)

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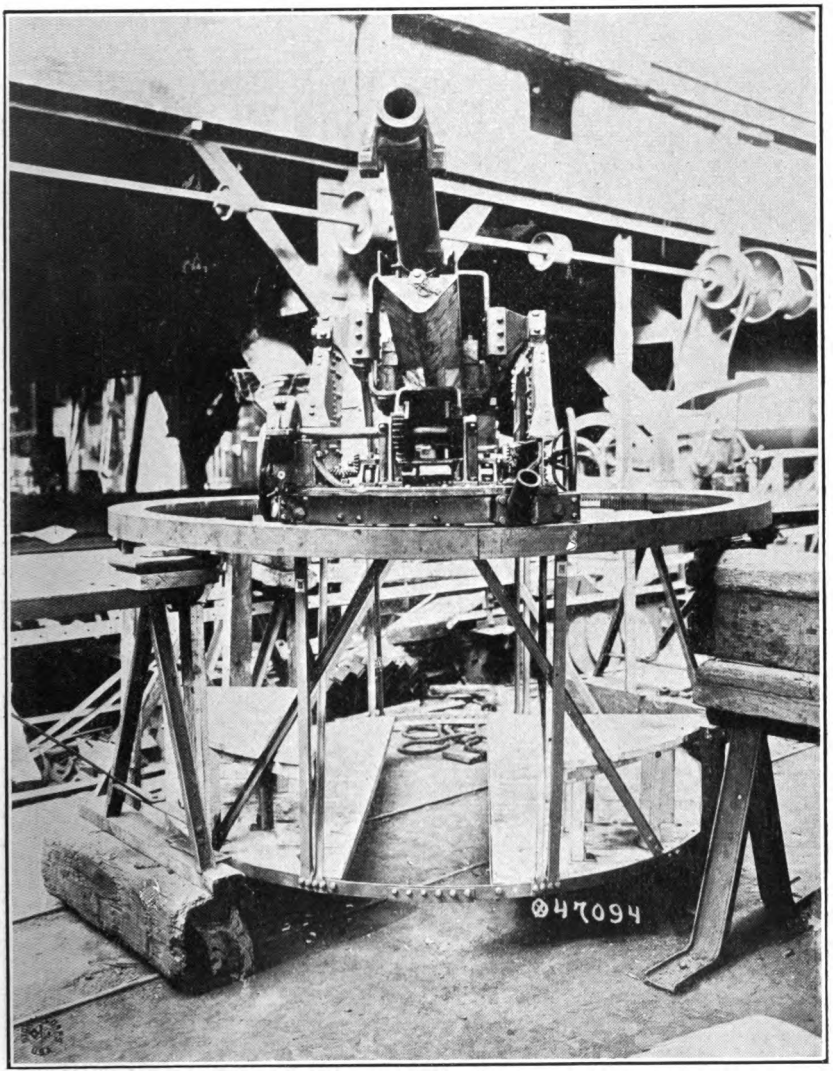

AMERICAN IMPROVISED ANTI-AIRCRAFT CARRIAGE, MODEL OF 1917, AFTER IT HAD BEEN CHANGED AND EQUIPPED WITH 75-MM. FRENCH MODEL 1897 FIELD GUN IN FRENCH SHOP.

Note changes in platform and change of horizontal supports to riveted U frame to provide better space for loading. (See p. 45.)

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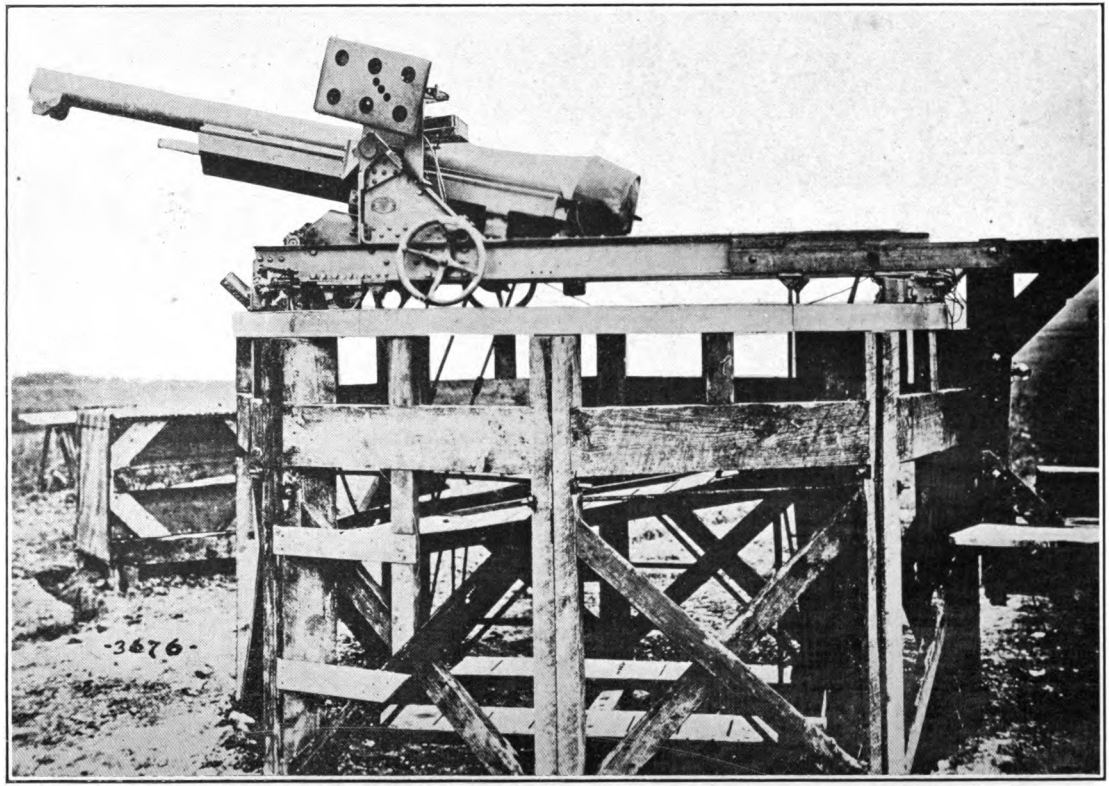

75-MM. FIELD GUN, FRENCH MODEL 1897, WITH PUTEAUX RECUPERATOR, FITTED WITH AMOURTISSEUR ON AMERICAN IMPROVISED PLATFORM MOUNT, FOR ANTI-AIRCRAFT SERVICE.

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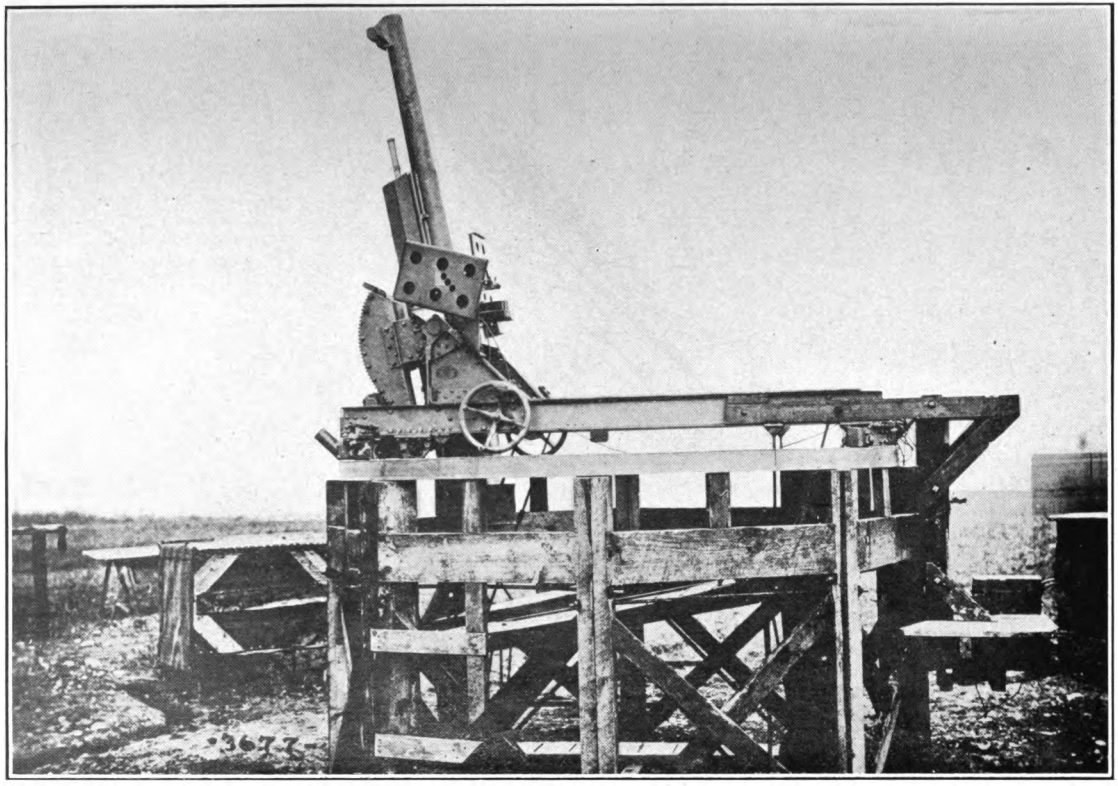

75-MM. FIELD GUN, FRENCH MODEL 1897, WITH PUTEAUX RECUPERATOR, FITTED WITH AMOURTISSEUR ON AMERICAN IMPROVISED PLATFORM MOUNT, FOR ANTIAIRCRAFT SERVICE AT MAXIMUM ELEVATION.

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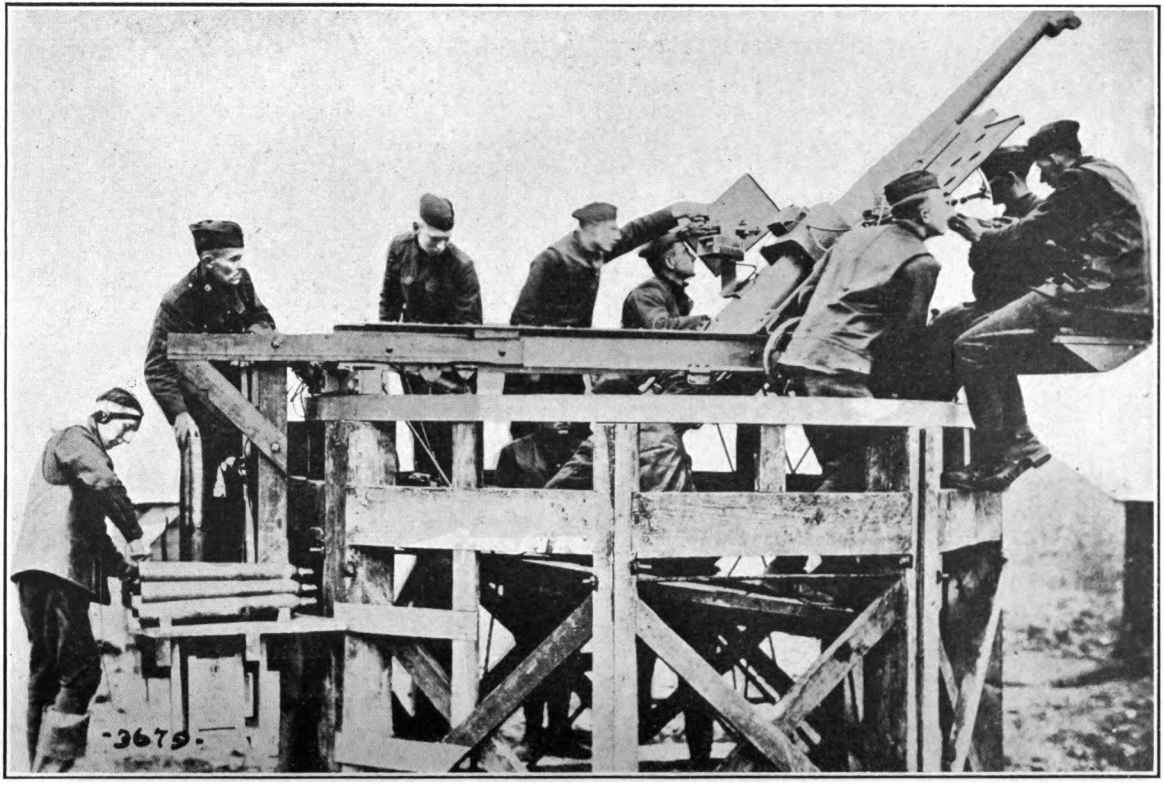

AMERICAN TROOPS OPERATING AMERICAN 75-MM. IMPROVISED MOUNT EQUIPMENT FOR ANTI-AIRCRAFT SERVICE.

Note arrangement of fuze punch, sighting apparatus, position of men on overhung seats and inside of mount structure.

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AMERICAN TROOPS OPERATING AMERICAN 75-MM. IMPROVISED MOUNT EQUIPMENT FOR ANTI-AIRCRAFT SERVICE.

Note fuze punch.

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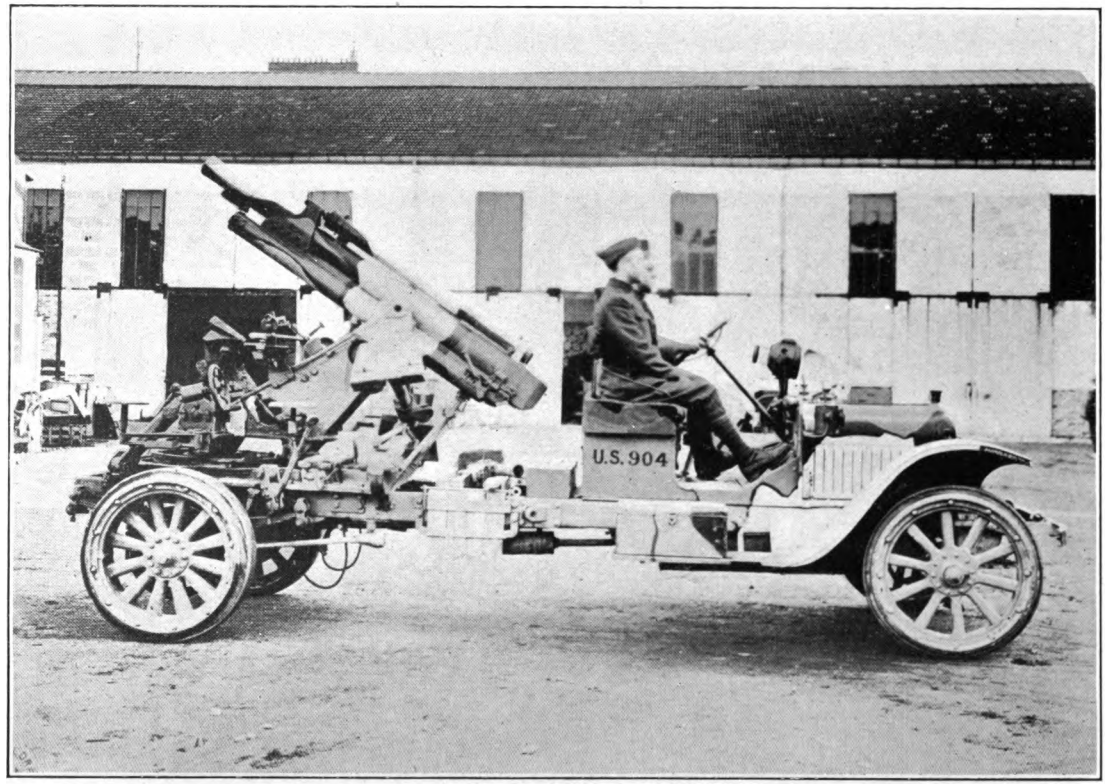

75-MM. ANTI-AIRCRAFT TRUCK MOUNT. TRAVELING POSITION. (See p. 46.)

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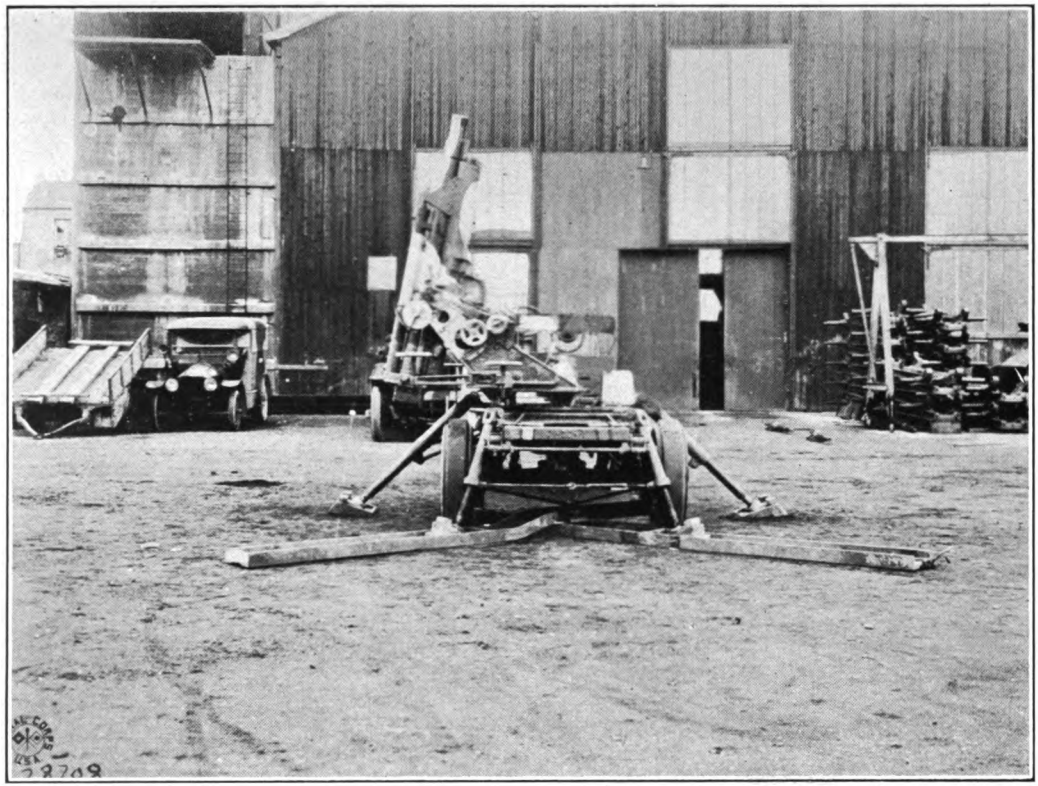

75-MM. ANTI-AIRCRAFT TRUCK MOUNT. FIRING POSITION WITH GUN ELEVATED AT 80°. (See p. 46.)

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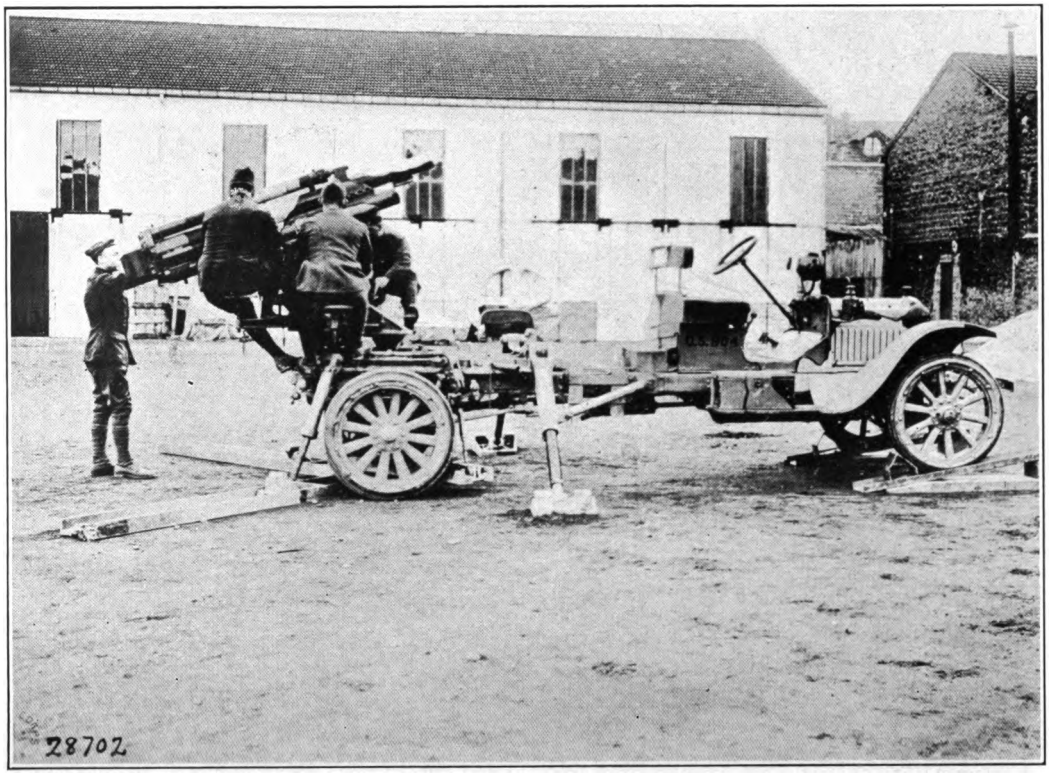

75-MM. ANTI-AIRCRAFT TRUCK MOUNT. FIRING POSITION. (See p. 46.)

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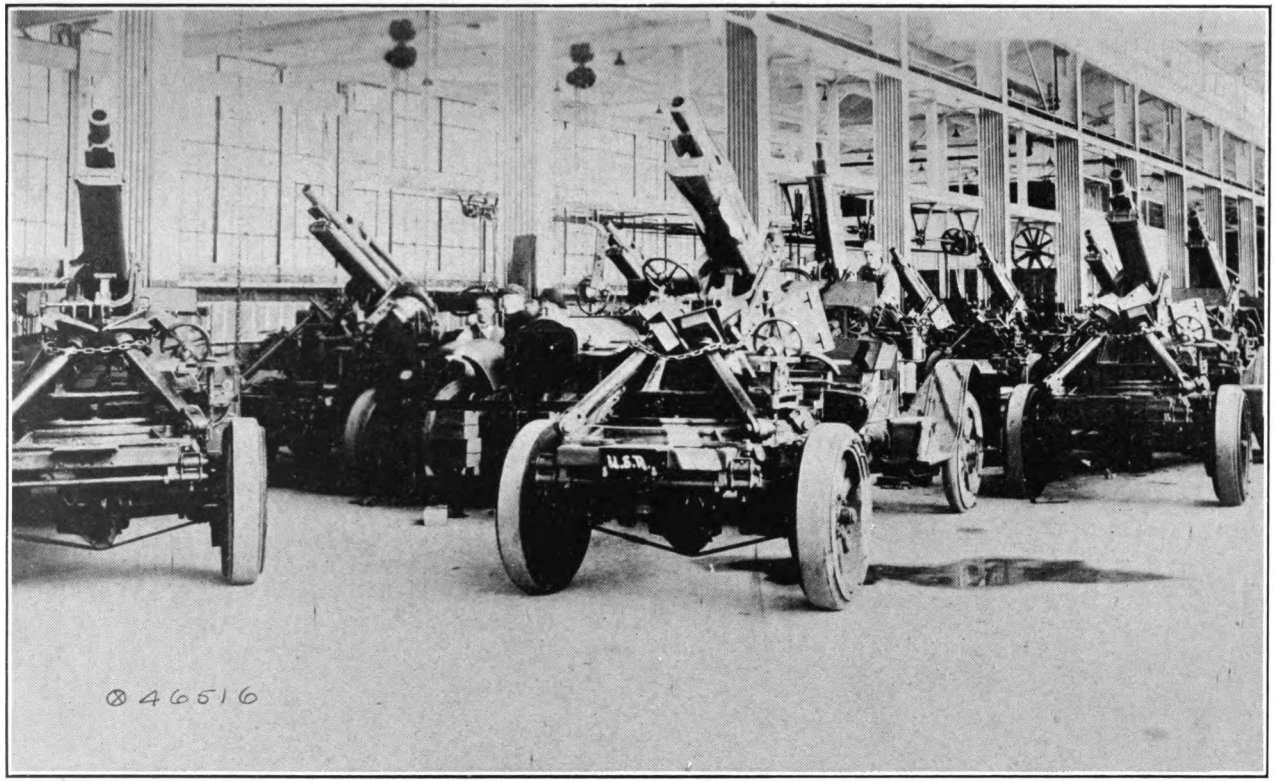

GROUP OF 75-MM. ANTI-AIRCRAFT TRUCK MOUNTS AT FACTORY, NEW BRITAIN, CONN. (See p. 46.)

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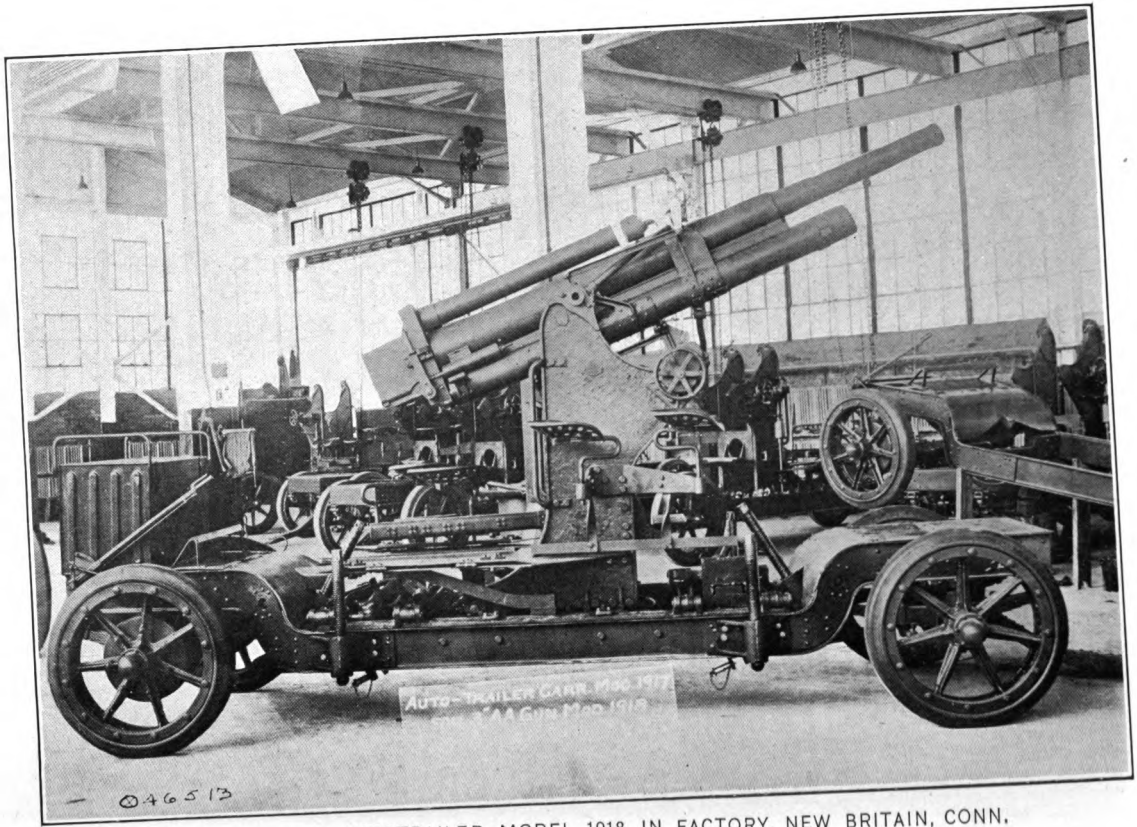

3-INCH ANTI-AIRCRAFT AUTOTRAILER, MODEL 1918, IN FACTORY, NEW BRITAIN, CONN.

Shows outriggers folded in on trailer for transport and jackscrews raised. (See p. 46.)

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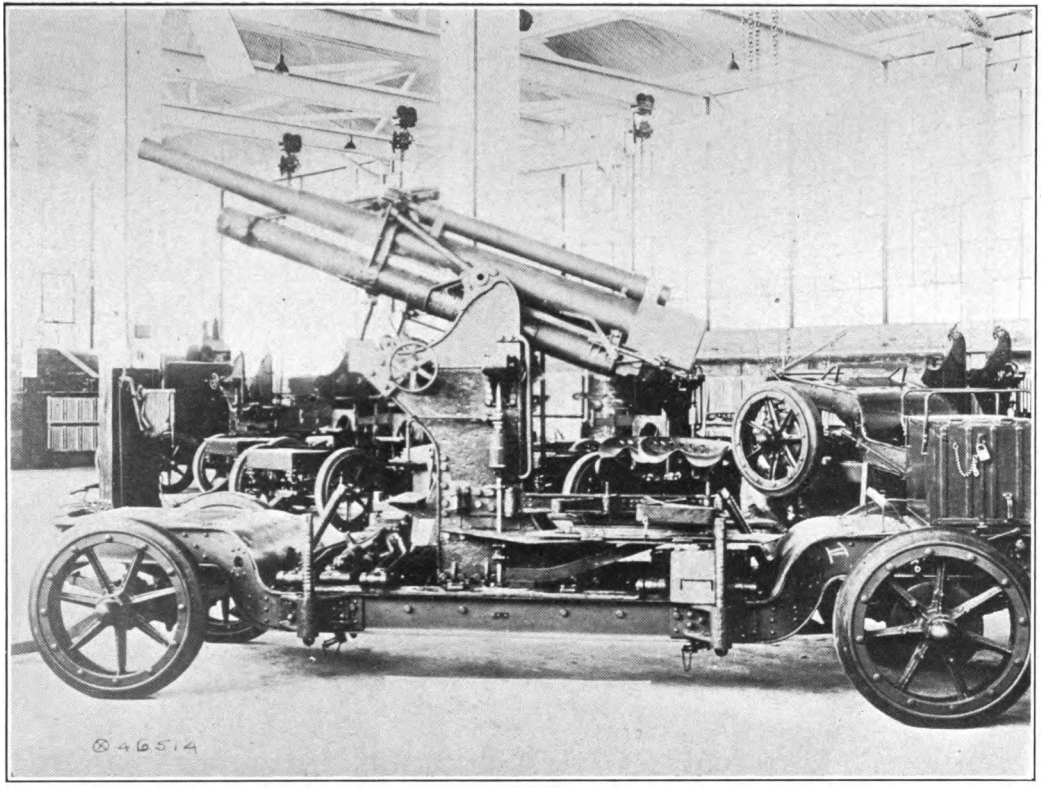

3-INCH ANTI-AIRCRAFT AUTOTRAILER, MODEL 1918, IN FACTORY AT NEW BRITAIN, CONN. TRAILERS MODEL 1917; GUN, MODEL 1918. (See pp. 46 and 47.)

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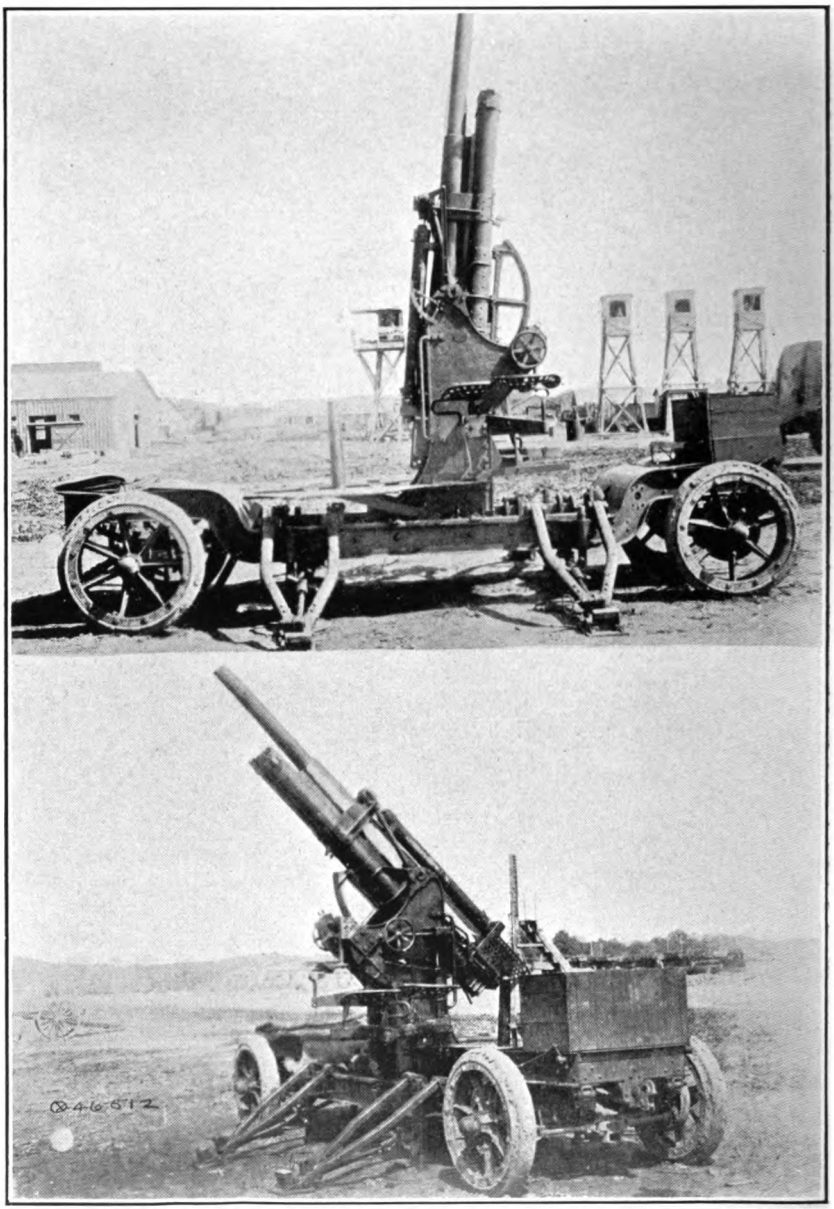

3-INCH ANTI-AIRCRAFT AUTOTRAILER, MODEL 1918, AT PROVING GROUNDS.

Two views in firing position with jacks and outriggers set. (See p. 46.)

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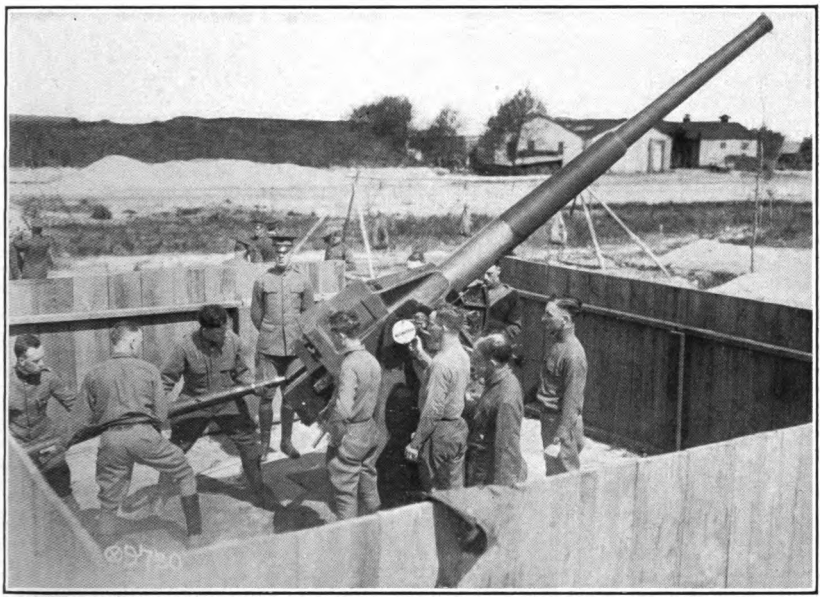
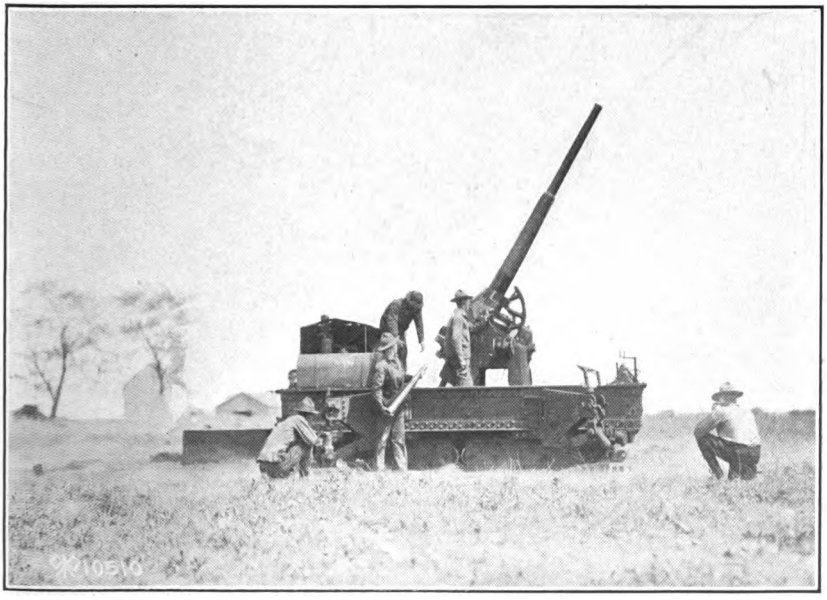
PLATE XV



AMERICANS LOADING 3-INCH ANTI-AIRCRAFT GUN, WITH PEDESTAL MOUNT.
Seacoast type, model 1917. (See p. 48.)

PLATE XVI



3-INCH ANTI-AIRCRAFT GUN, MODEL 1917, OF SEACOAST TYPE, MOUNTED ON CATERPILLAR TRAILER, ABERDEEN PROVING GROUND, MD., MAY, 1918. (See p. 48.)

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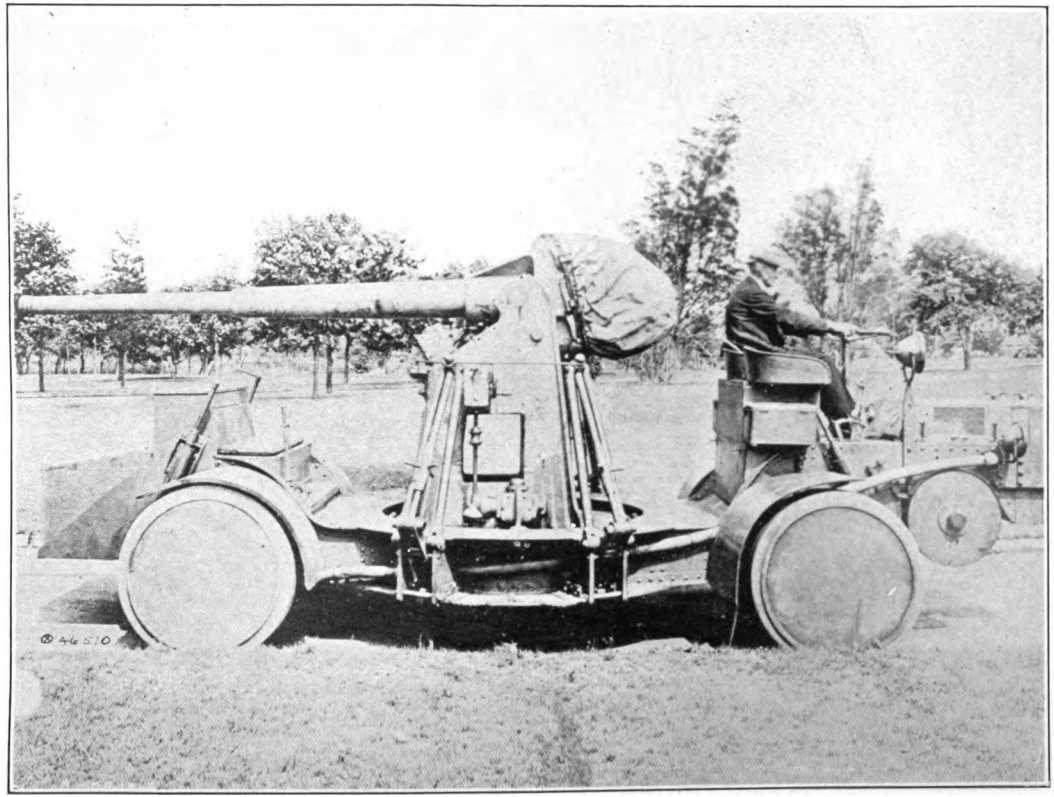

3-INCH ANTI-AIRCRAFT GUN, MODEL 1917, SEACOAST TYPE, MOUNTED ON 4-WHEEL TRUCK—IN TRANSPORT POSITION. (See p. 48.)

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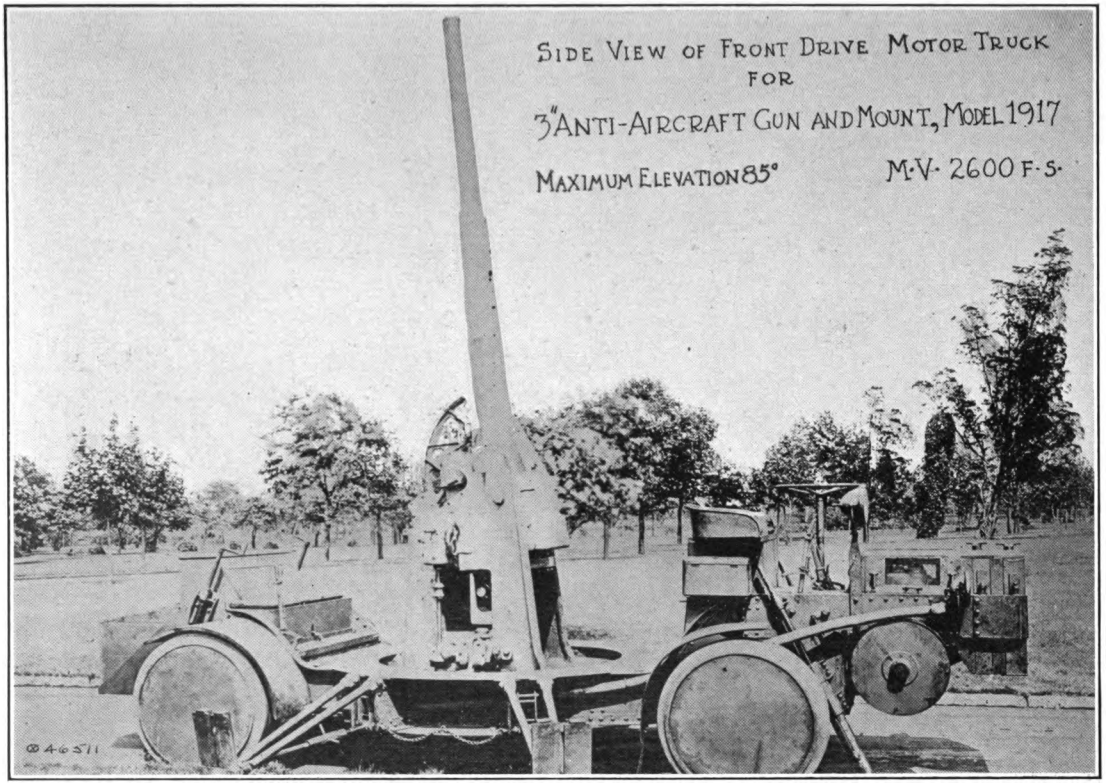

3-INCH ANTI-AIRCRAFT GUN, MODEL 1917, SEACOAST TYPE, MOUNTED ON 4-WHEEL TRUCK—IN FIRING POSITION, WITH JACKS AND OUTRIGGERS SET. (See p. 48.)

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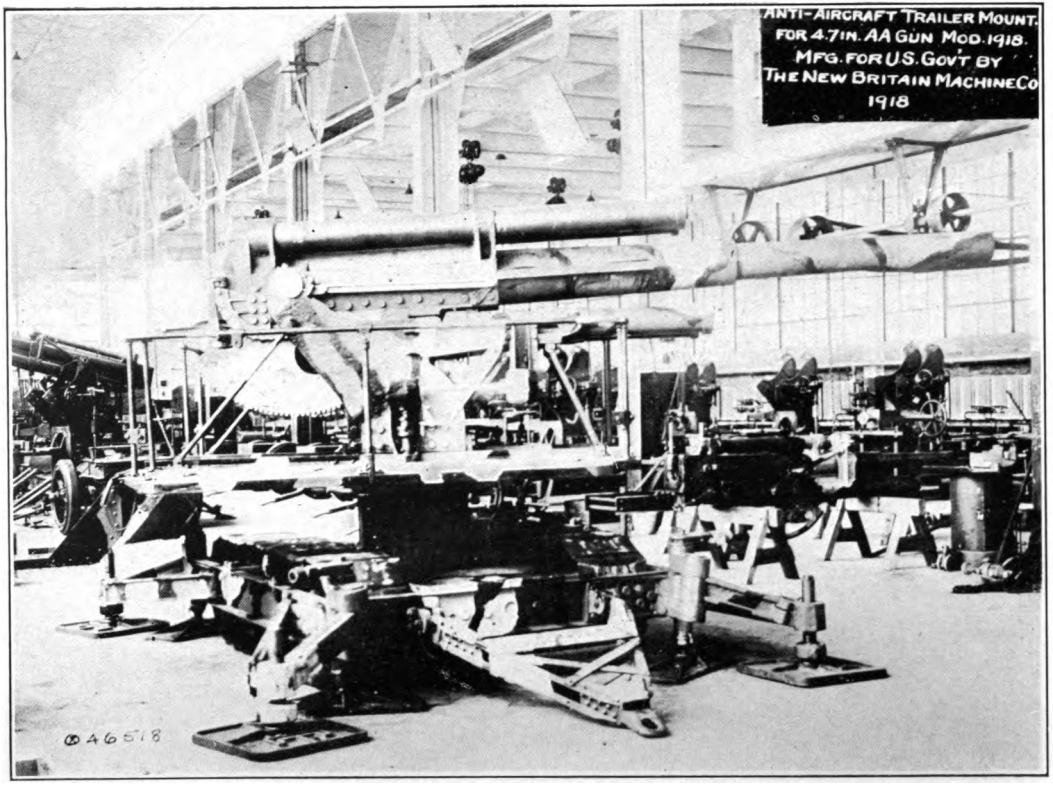

4.7-INCH ANTI-AIRCRAFT GUN, MODEL 1918.

Note horizontal spring cylinder and chain with cams for balancing weight of gun and recoil mechanism in trunnions. (See p. 51.)

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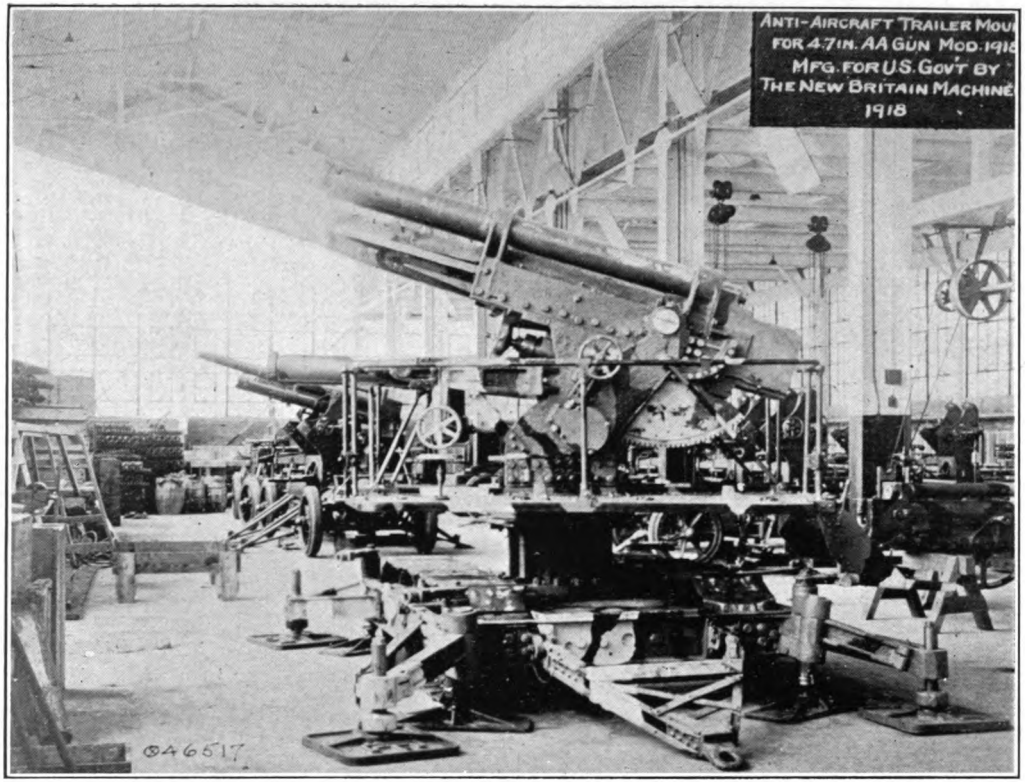

4.7-INCH ANTI-AIRCRAFT GUN, MODEL 1918, MOUNTED ON CATERPILLAR TRAILER, IN SHOP AT NEW BRITAIN, CONN.

Photo shows jacks and outriggers. (See p. 46.)

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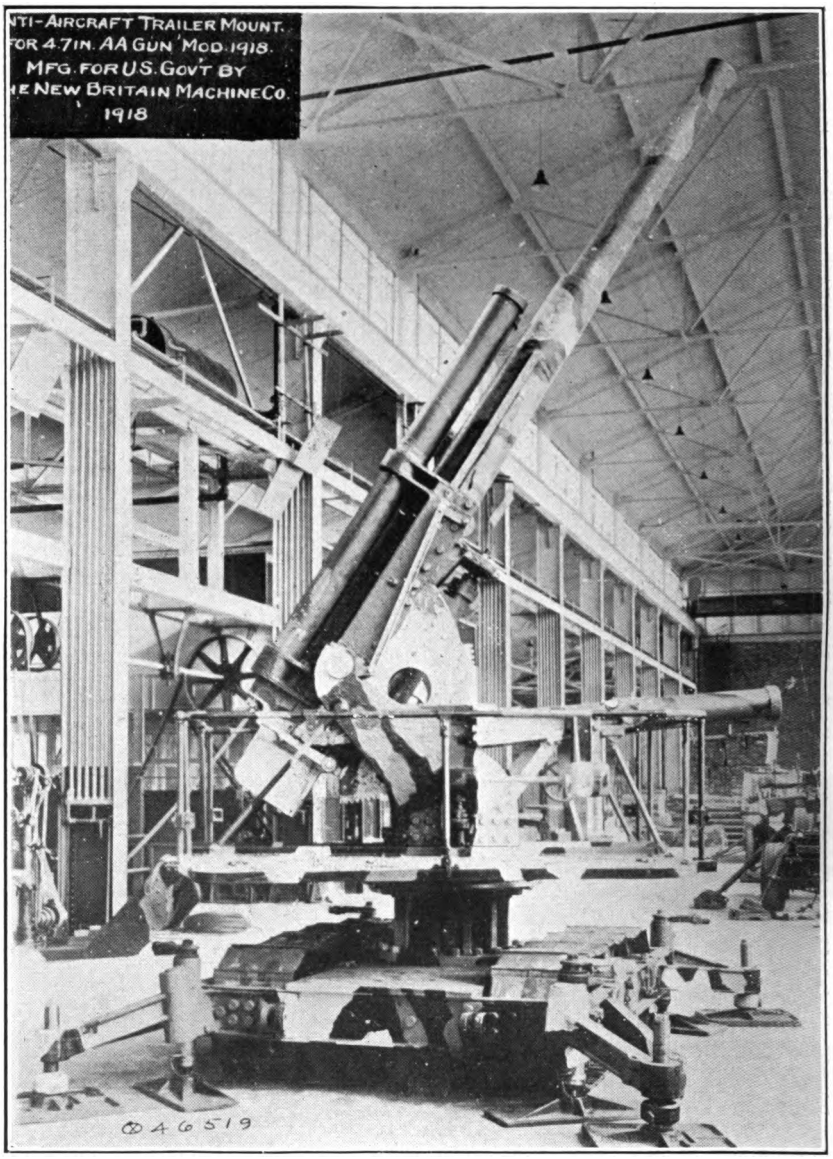

4.7-INCH ANTI-AIRCRAFT GUN, MODEL 1918.

Shows gun at high elevation and illustrates the spring-balancing feature. (See pp. 46 and 51.)

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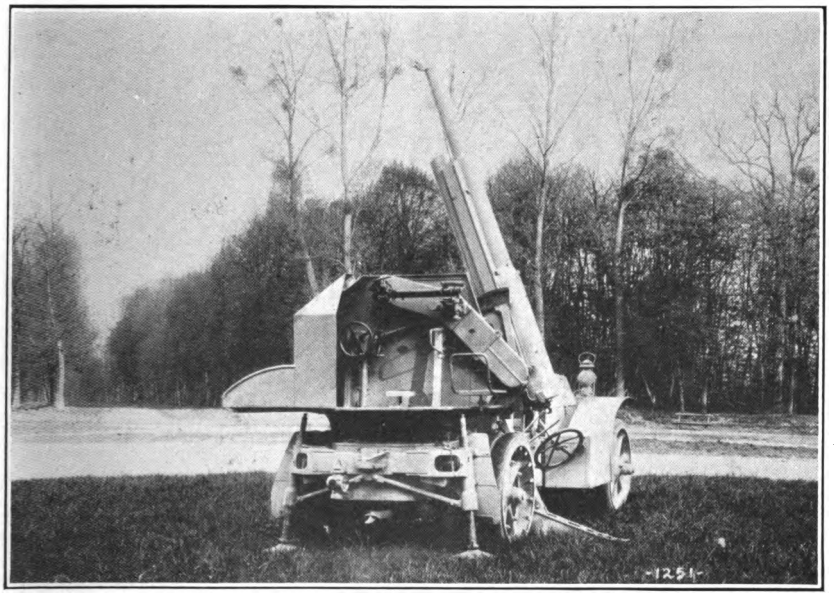
PLATE XXII



75-MM. ANTI-AIRCRAFT AUTO CANNON, MADE IN FRANCE.

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40-MM. VICKERS 2-POUNDER ANTI-AIRCRAFT GUN FORWARDED FROM ENGLAND TO BE TESTED AT ABERDEEN PROVING GROUND.

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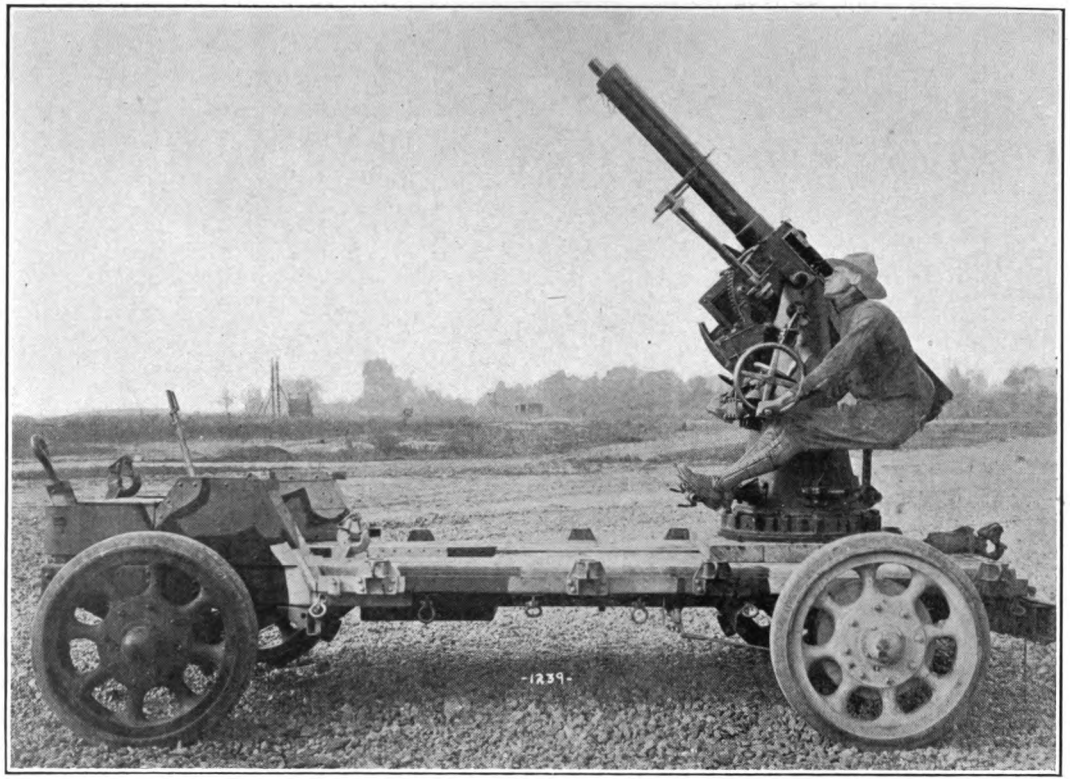

40-MM. VICKERS 2-POUNDER ANTI-AIRCRAFT GUN MOUNTED ON TRAILER. SIDE VIEW.
Gun sent from England to be tested at Aberdeen Proving Ground.

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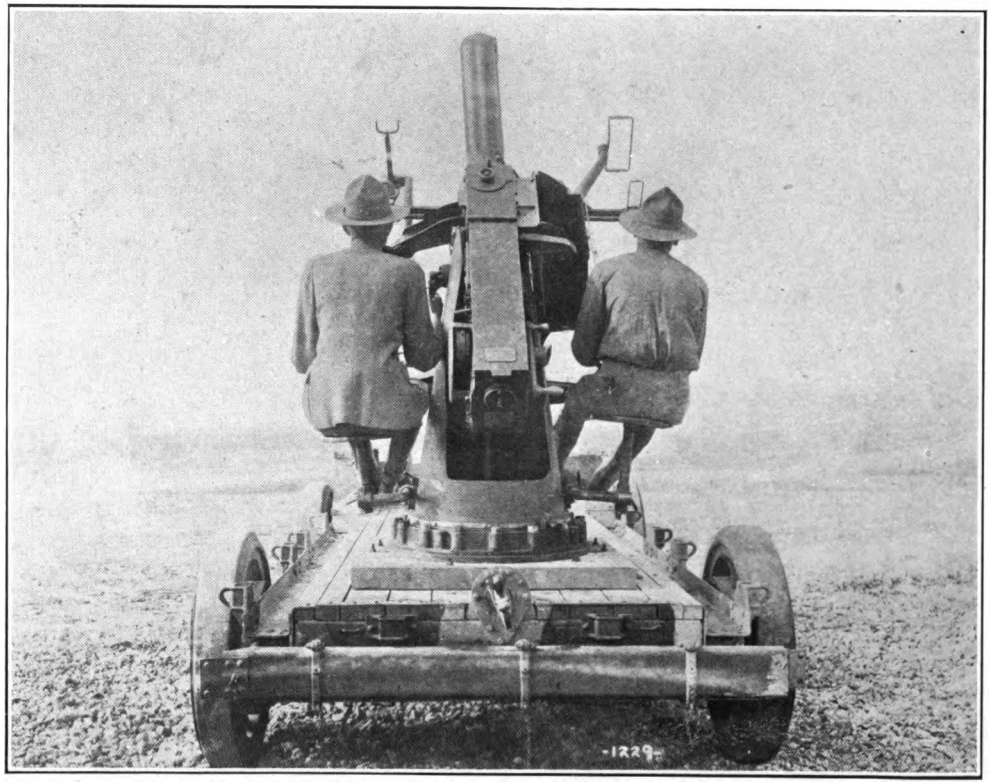

40-MM. VICKERS 2-POUNDER ANTI-AIRCRAFT GUN MOUNTED ON TRAILER. REAR VIEW.
Gun sent from England to be tested at Aberdeen Proving Ground.

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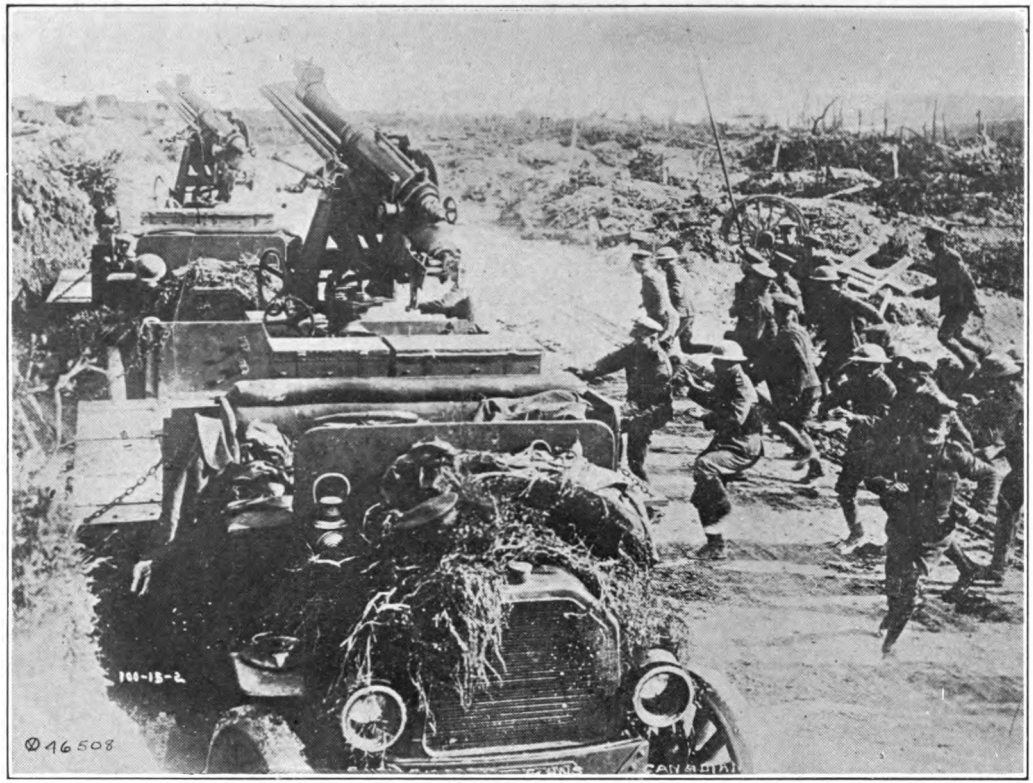

CANADIAN ANTI-AIRCRAFT GUN MOUNTED ON AUTOTRUCK IN ACTION. 13-Pounder (9 CWT.)

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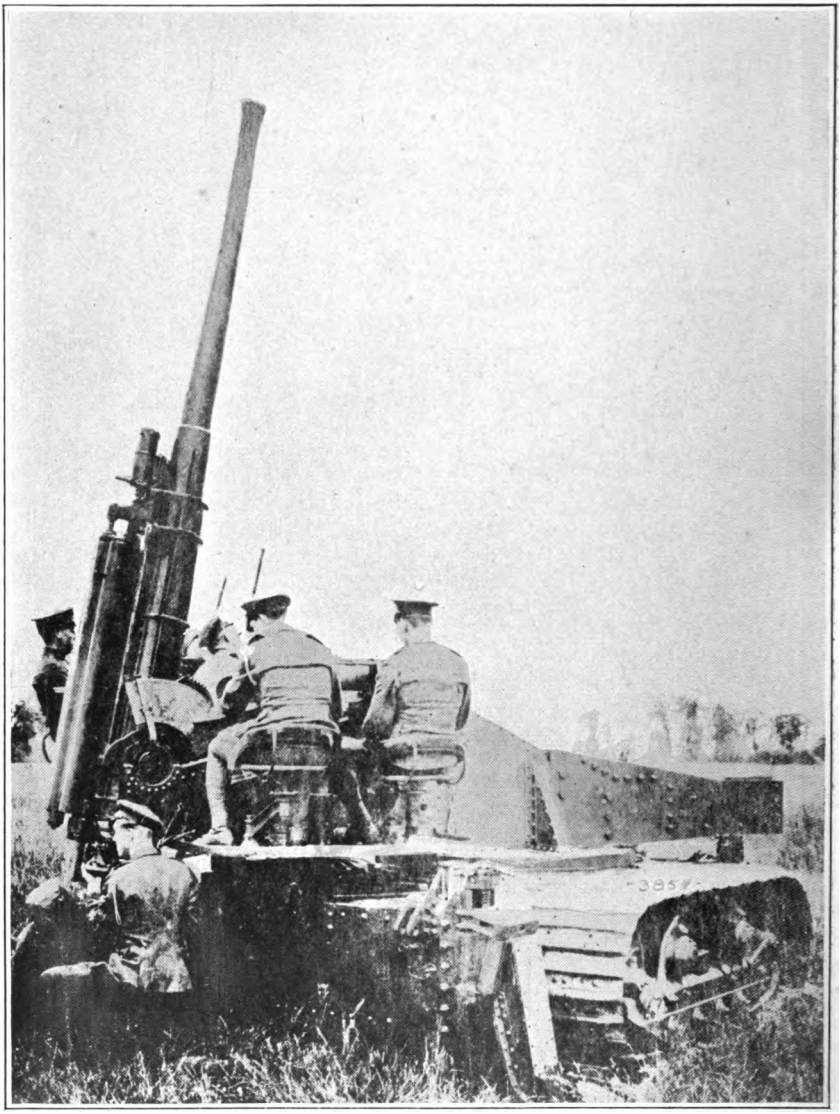

ENGLISH 3.6-INCH ANTI-AIRCRAFT GUN ON CATERPILLAR TRAILER MOUNT.

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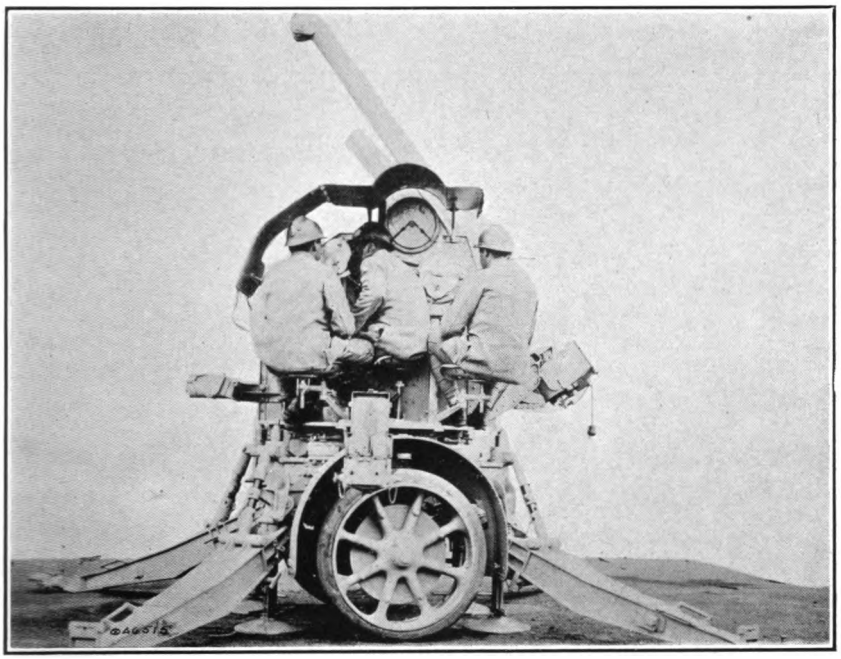
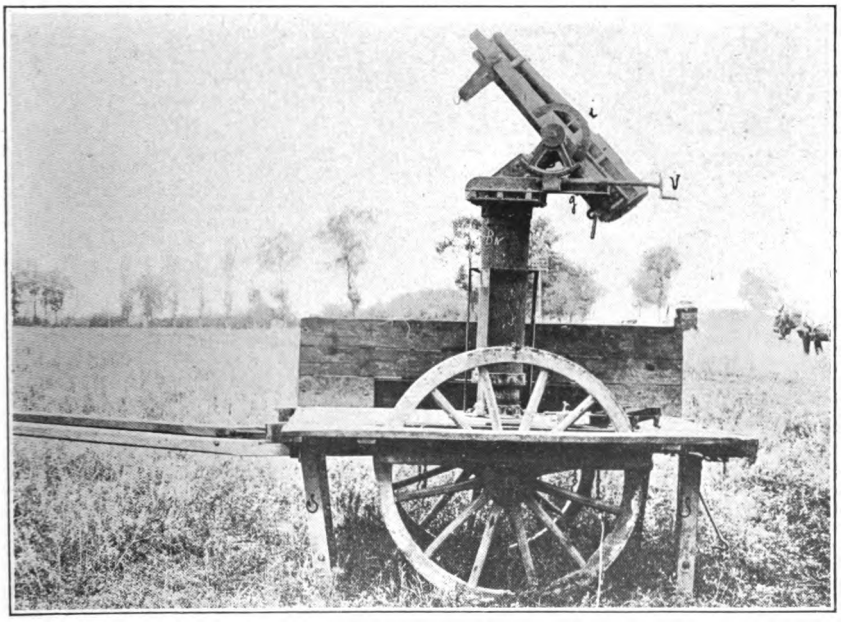
PLATE XXVIII



75-MM. ANTI-AIRCRAFT AUTOCANNON MOUNTED ON TRAILER WITH CREW.

PLATE XXIX



GERMAN 37-MM. REVOLVING CANNON, MOUNTED ON 2-WHEEL CART, WITH PROPS, FOR ANTI-AIRCRAFT SERVICE.

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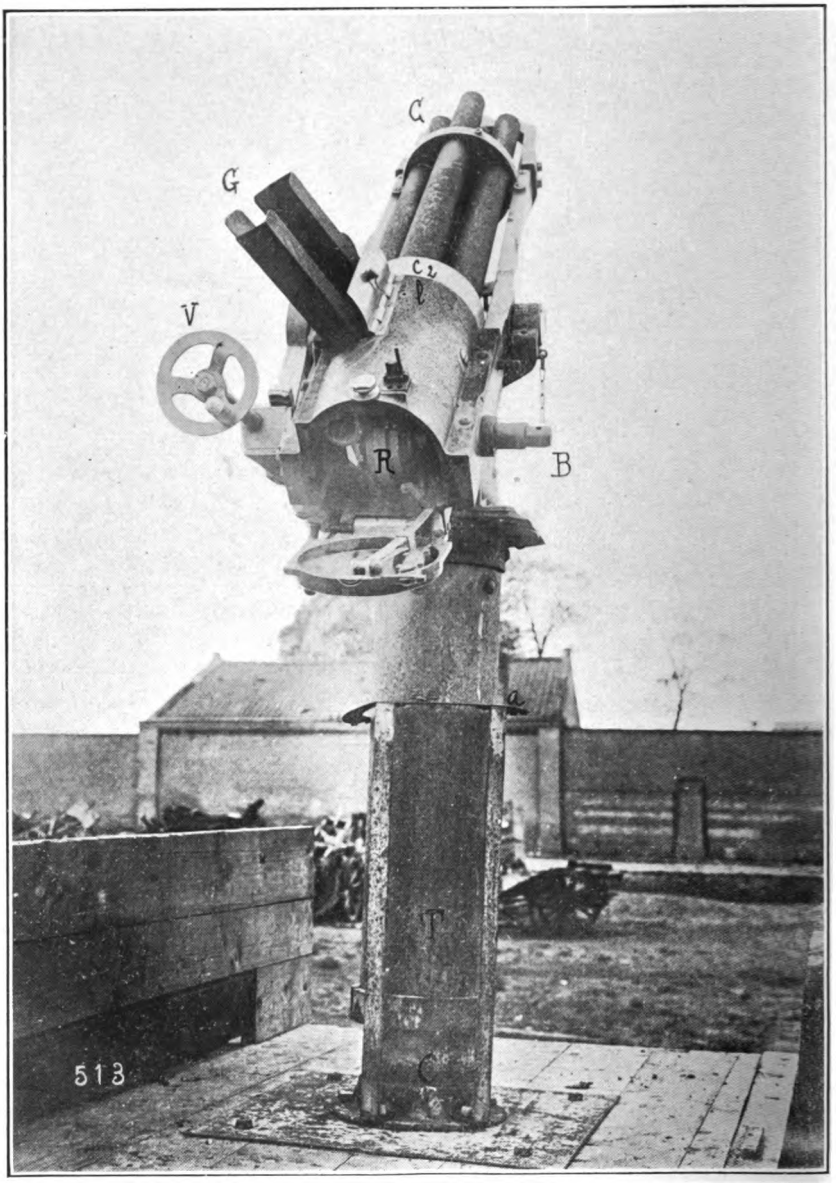
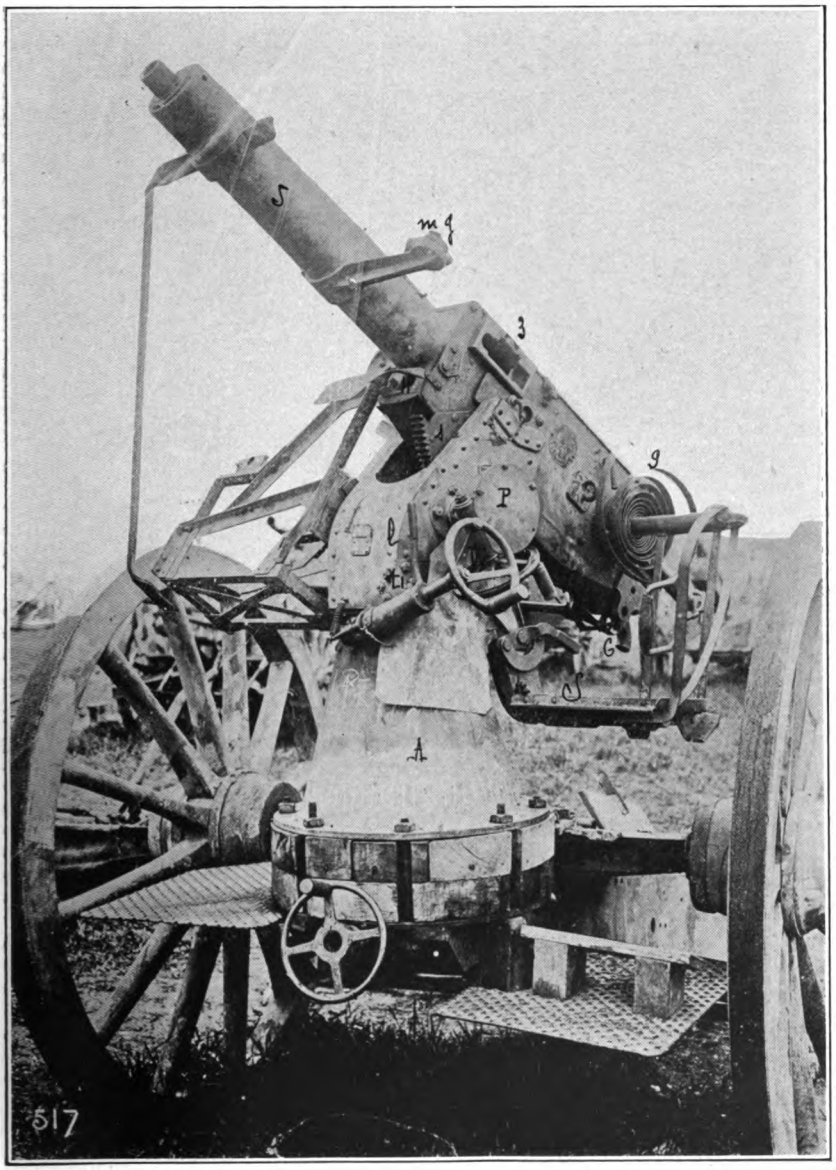


GERMAN 37-MM. REVOLVING CANNON FOR ANTI-AIRCRAFT SERVICE.

Digitized by Google

PLATE XXXI



GERMAN 37-MM. AUTOMATIC CANNON FOR ANTI-AIRCRAFT SERVICE.

124565—20——9

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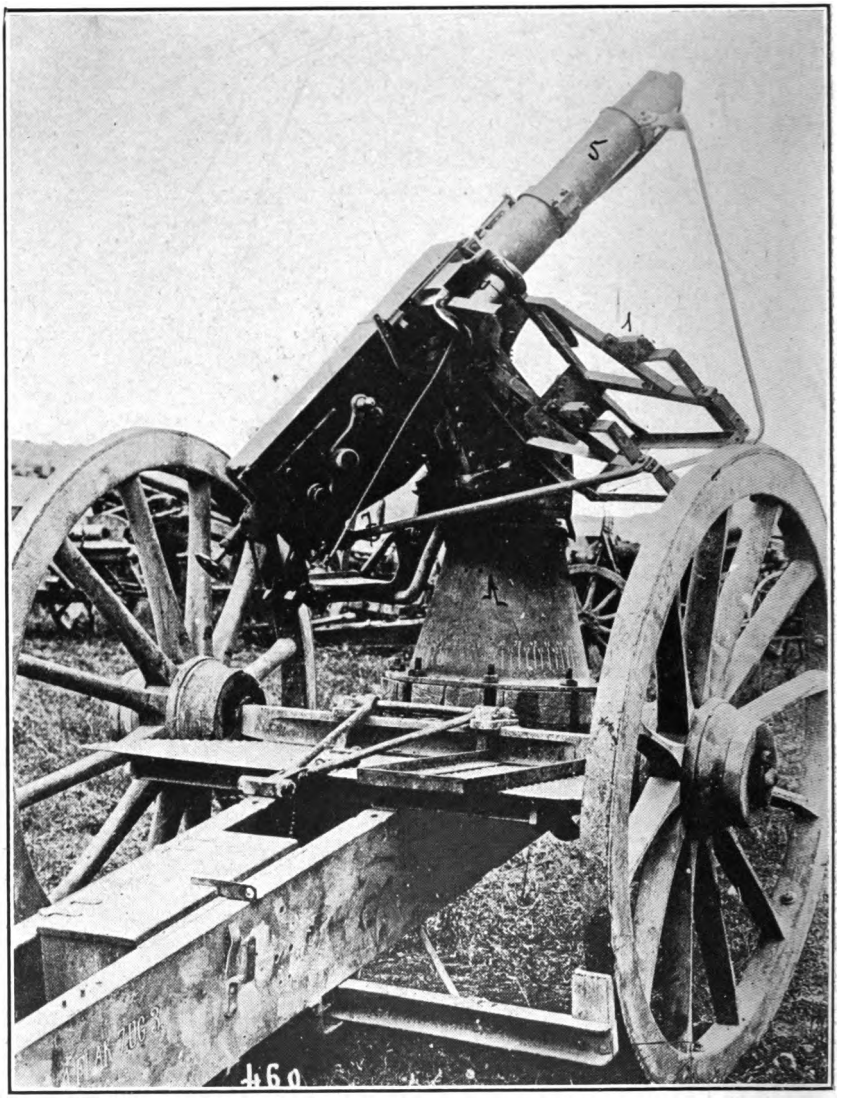
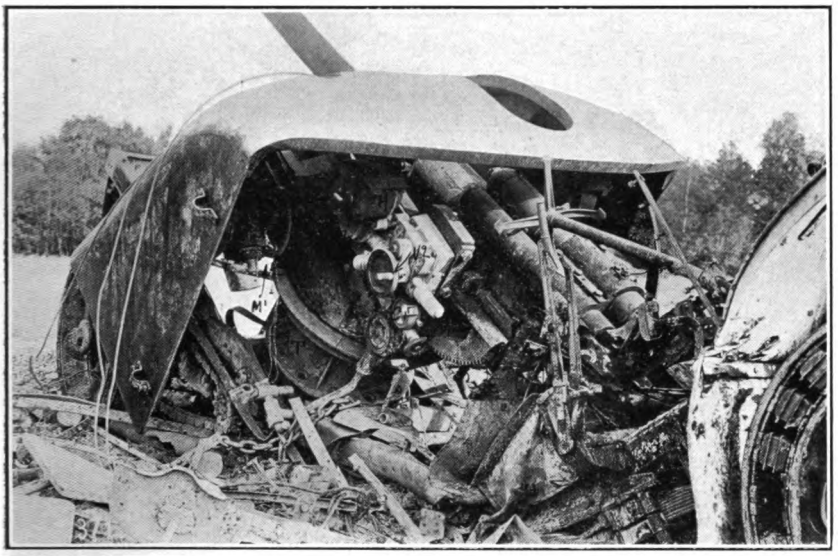


GERMAN 37-MM. AUTOMATIC CANNON FOR ANTI-AIRCRAFT SERVICE.

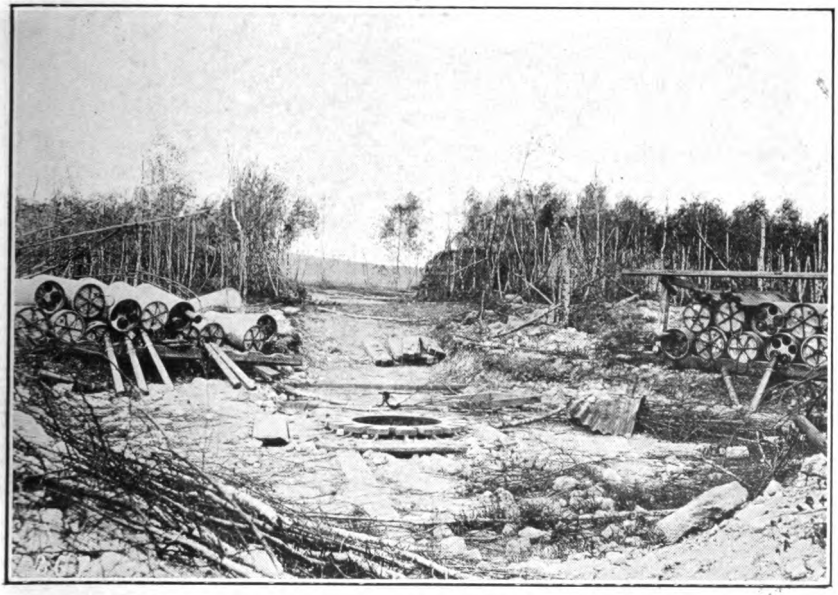
Digitized by Google

PLATE XXXIII



GERMAN TRUCK USED FOR TRANSPORTING SEMIFIXED 88-MM. GUN FOR ANTI-AIRCRAFT SERVICE.

PLATE XXXIV



GERMAN SEMIFIXED MOUNT FOR 88-MM. GUN FOR ANTI-AIRCRAFT SERVICE.

Note ammunition and transportation drums for same at side of photo.

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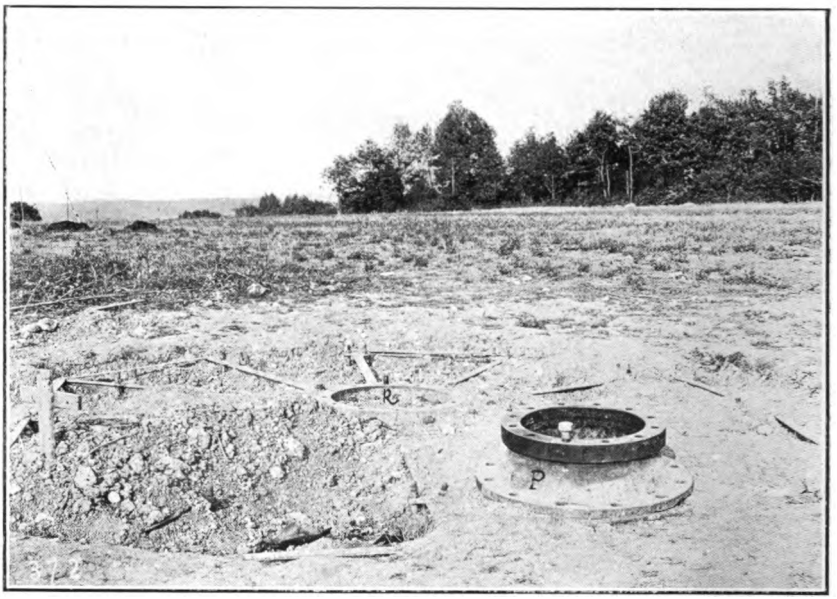
PLATE XXXV



GERMAN SEMIFIXED MOUNT FOR 88-MM. GUN FOR ANTI-AIRCRAFT SERVICE.
Note radial bracing from central pedestal mount.

PLATE XXXVI

GERMAN AUTOMOBILE MOUNT, 77-MM. GUN, FOR ANTI-AIRCRAFT SERVICE.

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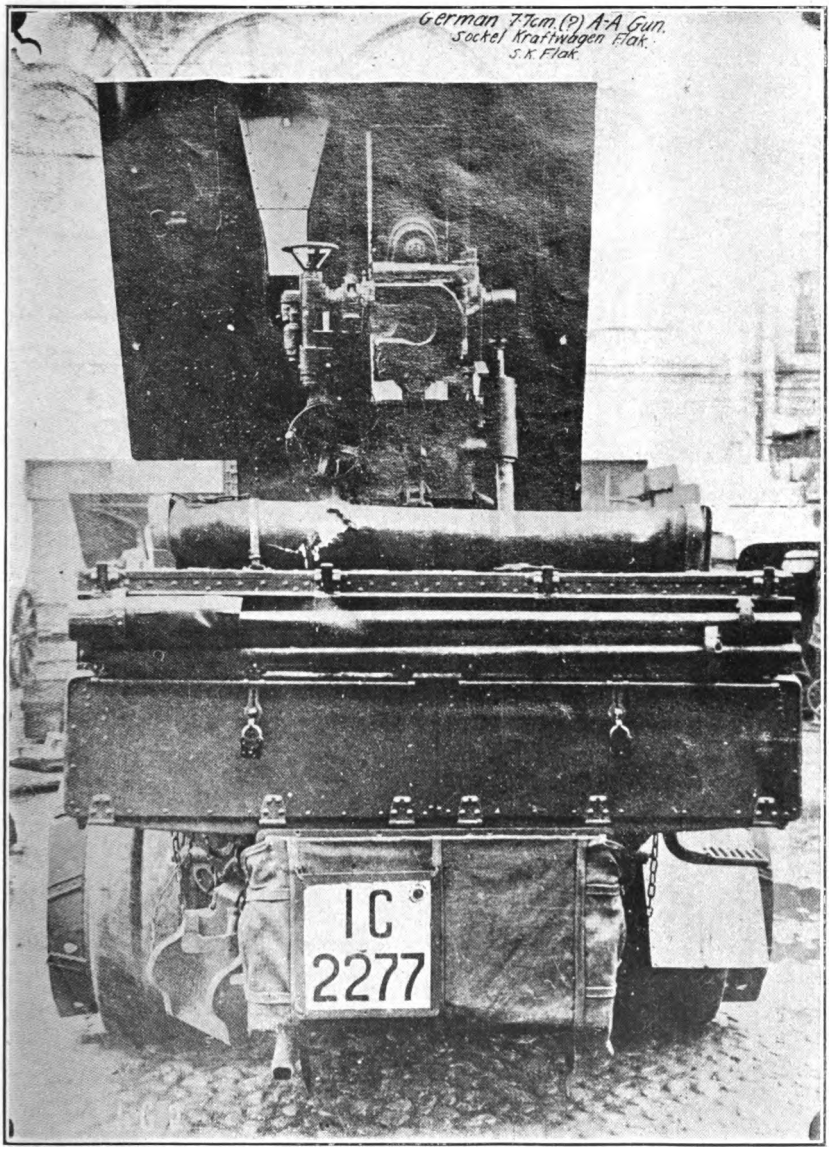

GERMAN AUTOMOBILE MOUNT, 77-MM. GUN, FOR ANTI-AIRCRAFT SERVICE.

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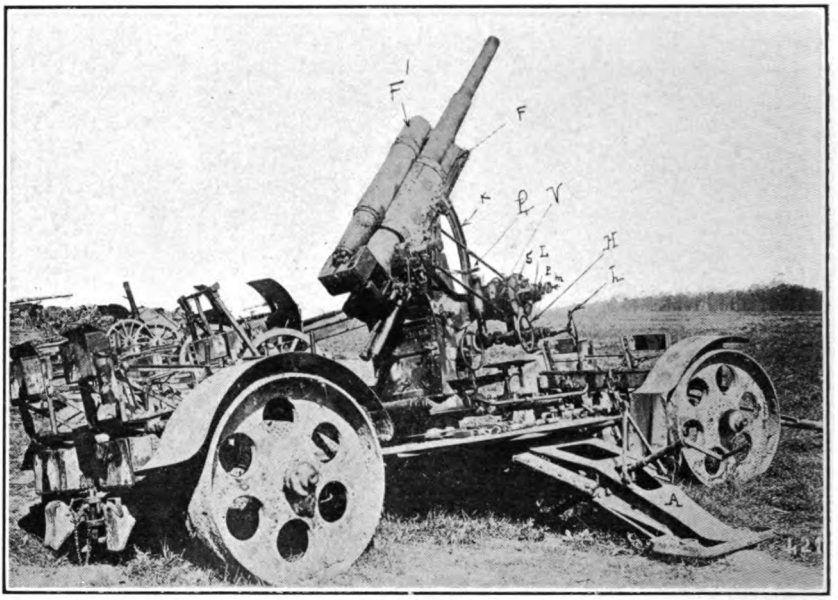
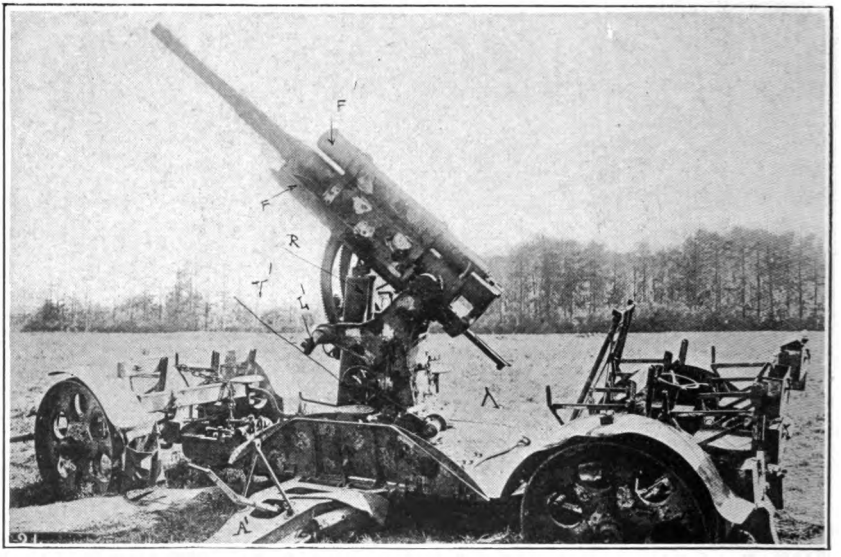
PLATE XXXVIII



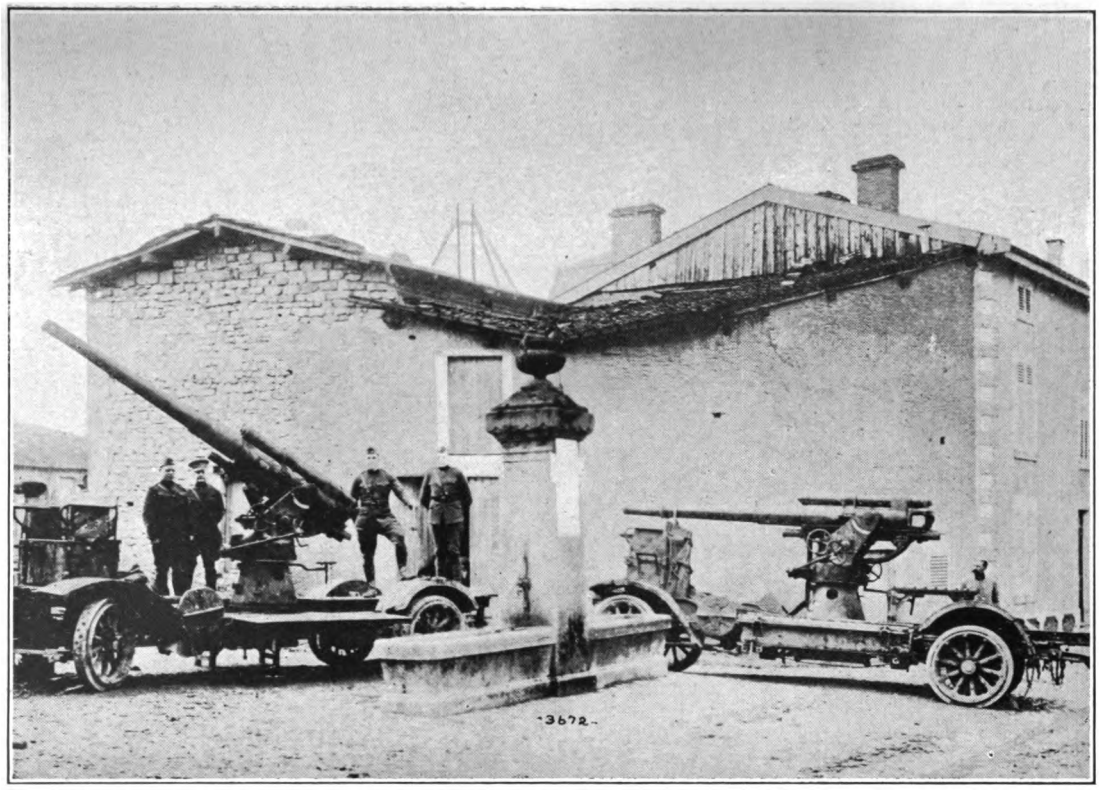
GERMAN TRAILER MOUNT, 88-MM. GUN, FOR ANTI-AIRCRAFT SERVICE.

PLATE XXXIX



GERMAN TRAILER MOUNT, 88-MM. GUN, FOR ANTI-AIRCRAFT SERVICE.

Digitized by Google



GERMAN 88-MM. ANTI-AIRCRAFT GUNS MOUNTED ON TRAILERS.

Captured near Conflans and Ville Au Montois and sent to Mehun with recommendations that they be forwarded to Aberdeen Proving Ground. These guns not fired by A. E. F., but give indications of excellent design and stability.

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CAPTURED GERMAN 88-MM. ANTI-AIRCRAFT GUN MOUNTED ON TRAILER.

Wheels have steel tires. When set for firing, weight of truck is supported on jacks, and steel outriggers are set at the sides of truck.

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REAR VIEW OF CAPTURED GERMAN 88-MM. ANTI-AIRCRAFT GUN MOUNTED ON TRAILER.

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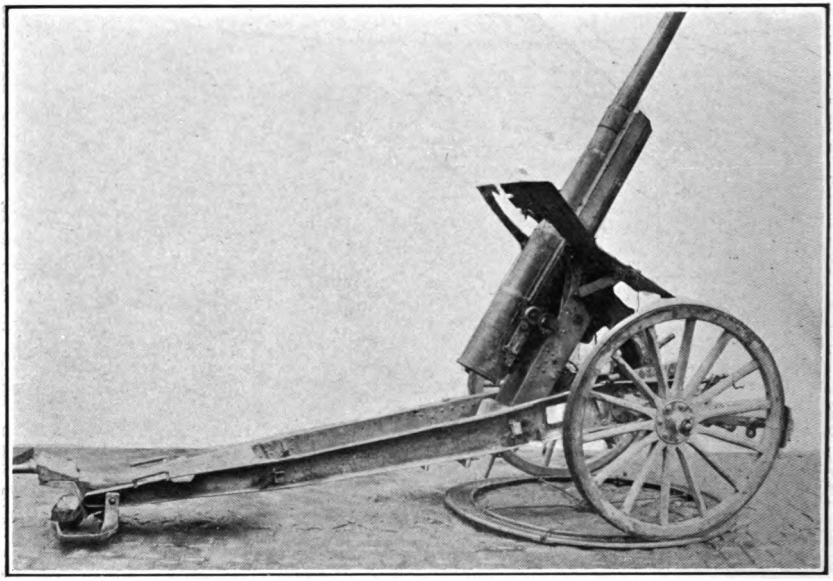
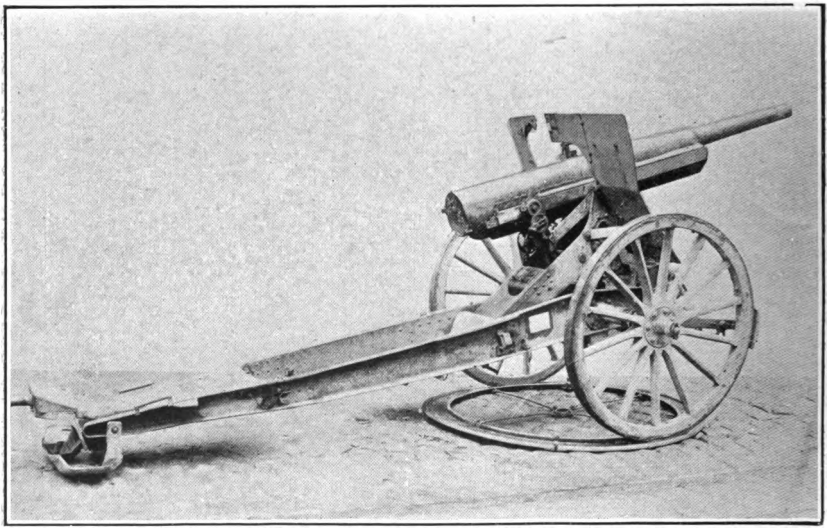
PLATE XLIII



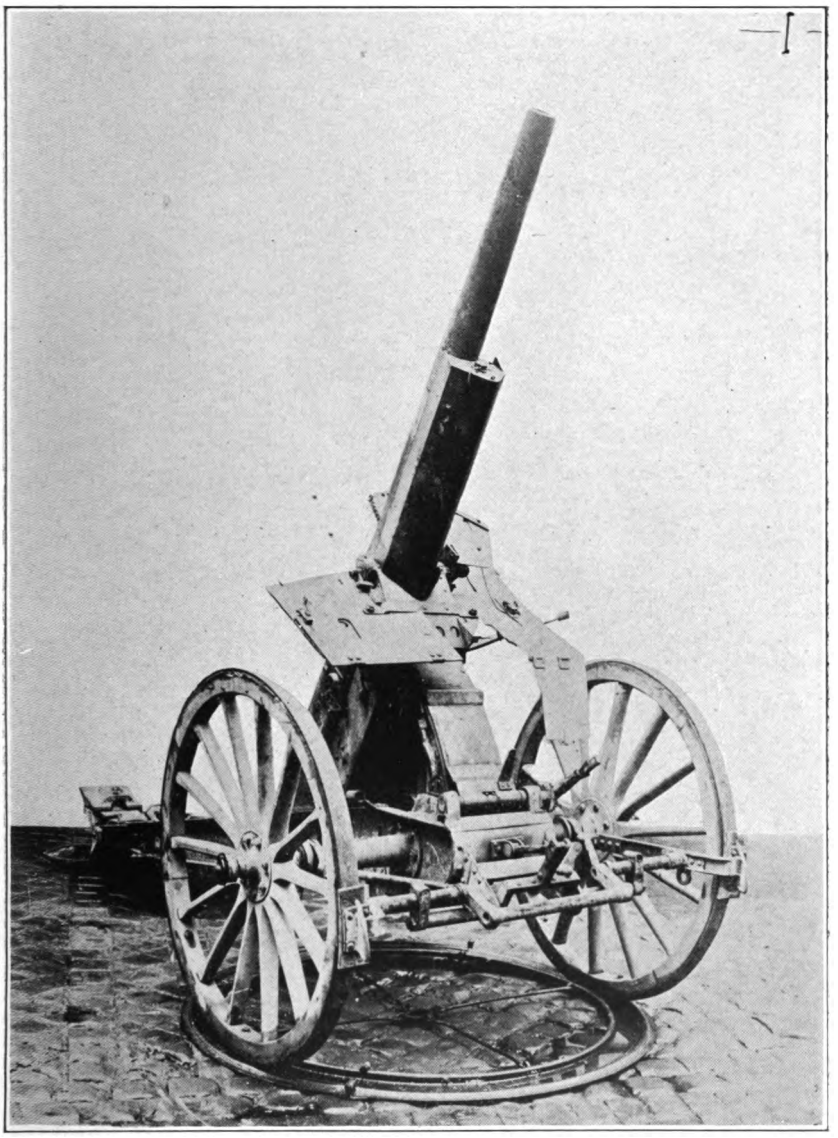
GERMAN TRANSFORMED 75-MM. FIELD GUN, FRENCH MODEL 1897, REBORED TO 77 MM., USED FOR ANTI-AIRCRAFT SERVICE.

PLATE XLIV



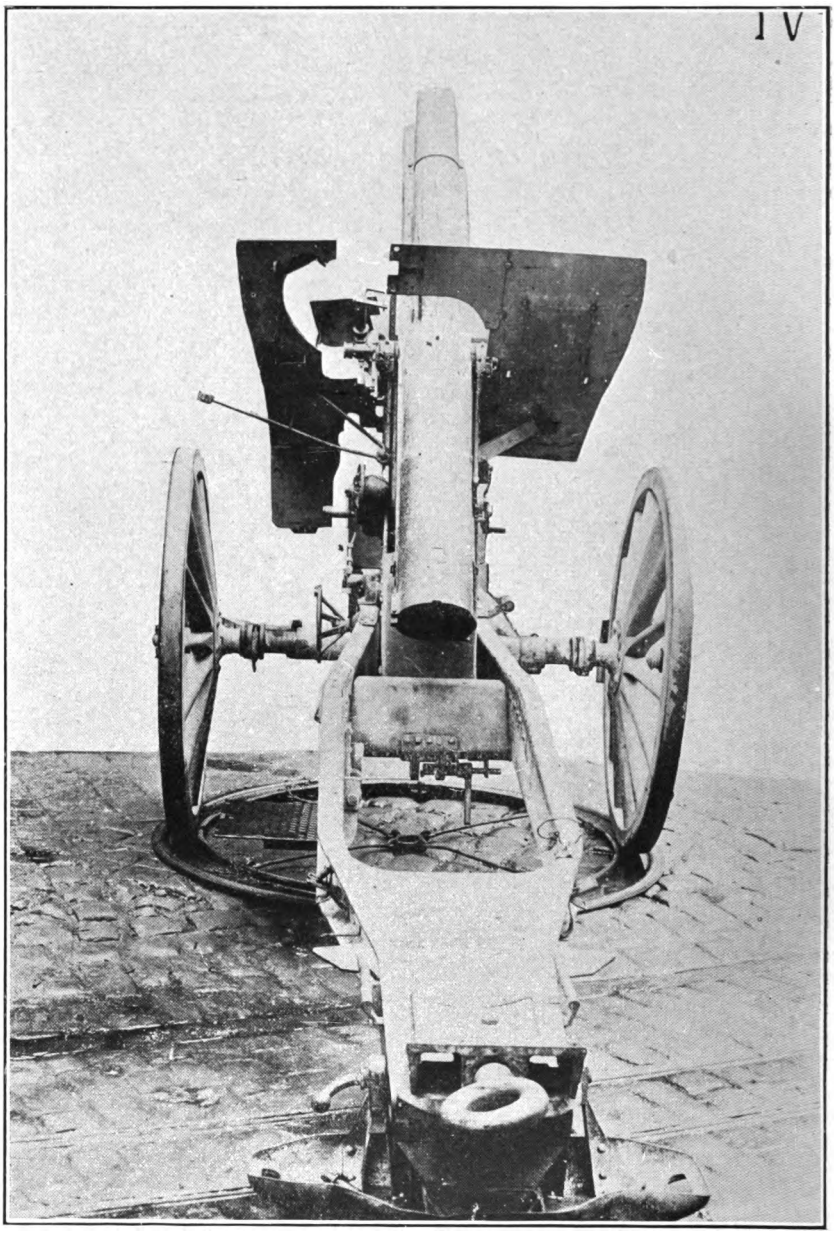
GERMAN TRANSFORMED 75-MM. FIELD GUN, FRENCH MODEL 1897, REBORED TO 77 MM., USED FOR ANTI-AIRCRAFT SERVICE.

Digitized by Google



GERMAN TRANSFORMED 75-MM. FIELD GUN, FRENCH MODEL 1897, REBORED TO 77 MM., USED FOR ANTI-AIRCRAFT SERVICE.

Digitized by Google



GERMAN TRANSFORMED 75-MM. FIELD GUN, FRENCH MODEL 1897, REBORED TO 77 MM., USED FOR ANTI-AIRCRAFT SERVICE.

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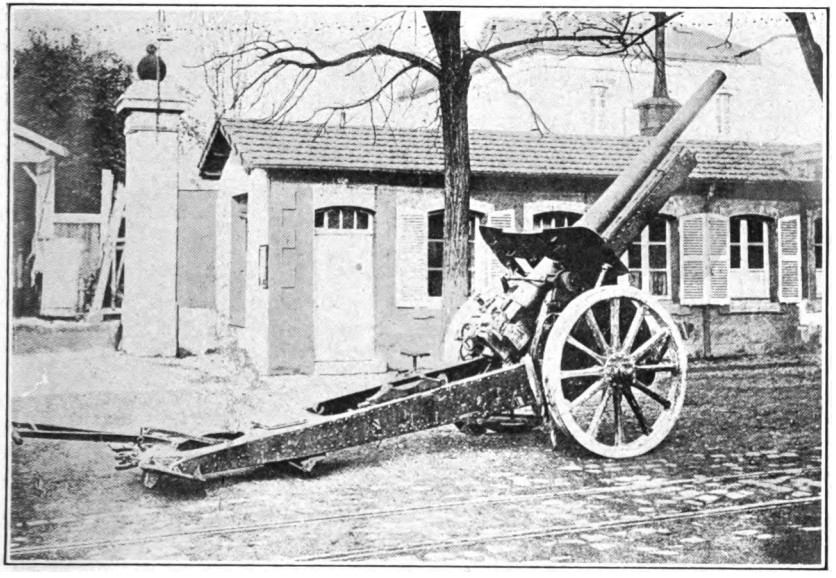
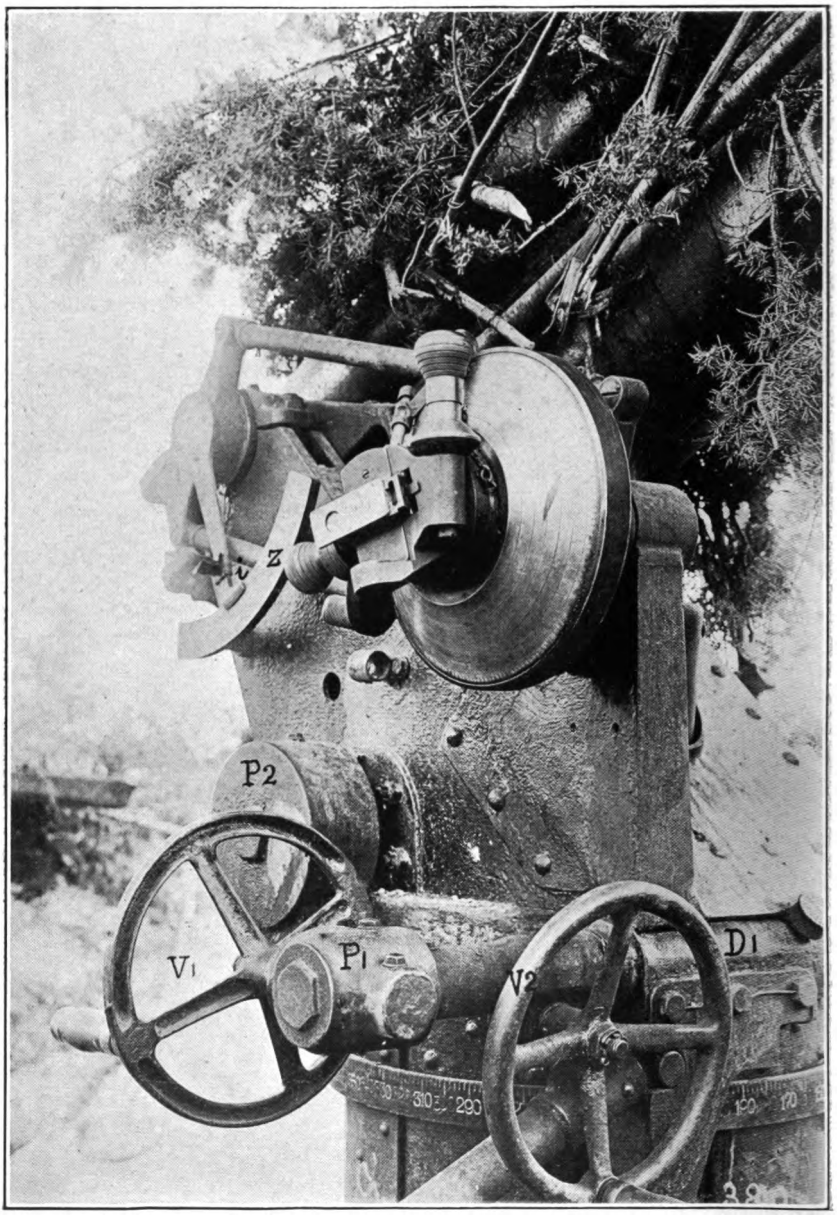
PLATE XLVII



GERMAN 100-MM. GUN USED FOR ANTI-AIRCRAFT SERVICE.

Digitized by Google



GERMAN POUTILOFF(?), RUSSIAN 76.2-MM. GUN, USED FOR ANTI-AIRCRAFT SERVICE.

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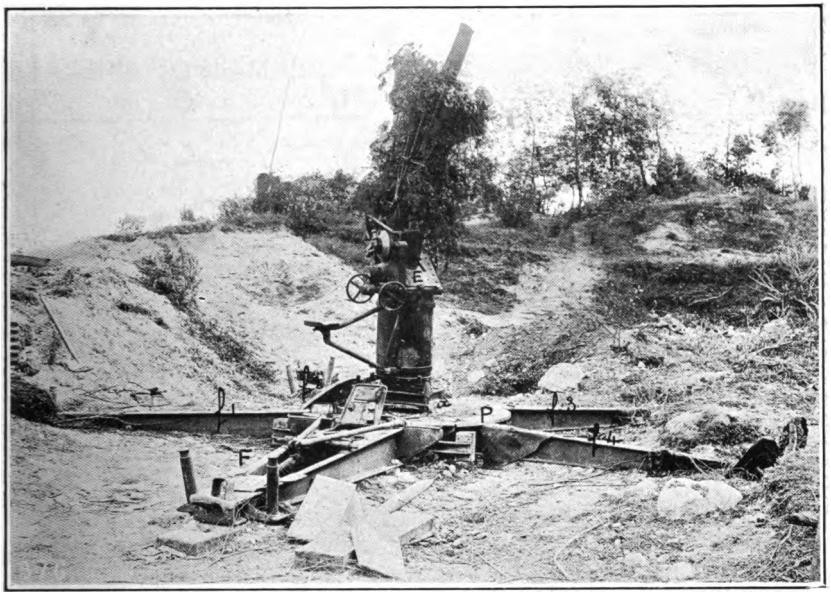
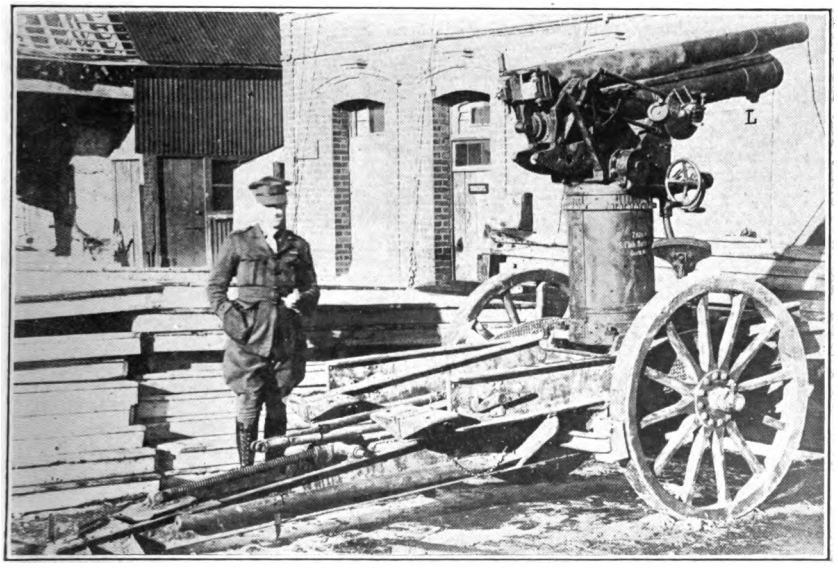
PLATE XLIX



GERMAN POUTILOFF(?), RUSSIAN 76.2-MM. GUN, USED FOR ANTI-AIRCRAFT SERVICE.

PLATE L



GERMAN POUTILOFF(?), RUSSIAN 76.2-MM. GUN, USED FOR ANTI-AIRCRAFT SERVICE.

Arranged for transportation.

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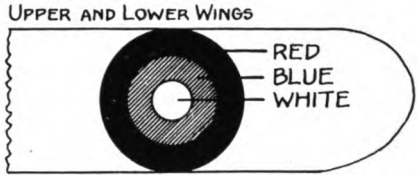
PUBLICATION NO. 35
OFFICE OF NAVAL INTELLIGENCE
NAVY DEPARTMENT

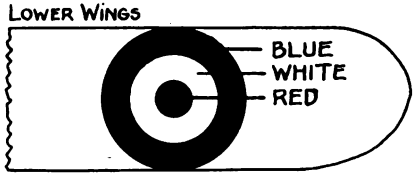
JUNE, 1918

DIAGRAM TO SHOW DISTINCTIVE MARKINGS OF AIRPLANES AS USED IN PRESENT WAR, 1918

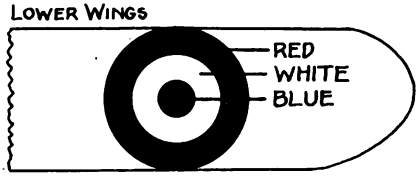
U.S.



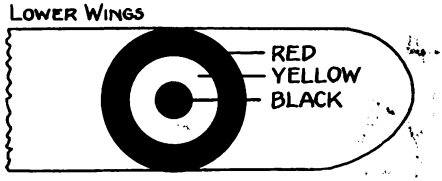
BRITISH



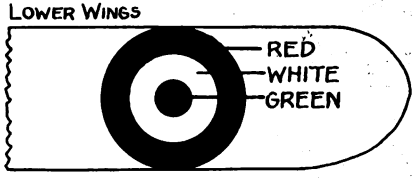
FRENCH



BELGIAN



ITALIAN



GERMAN

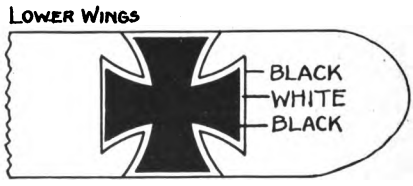


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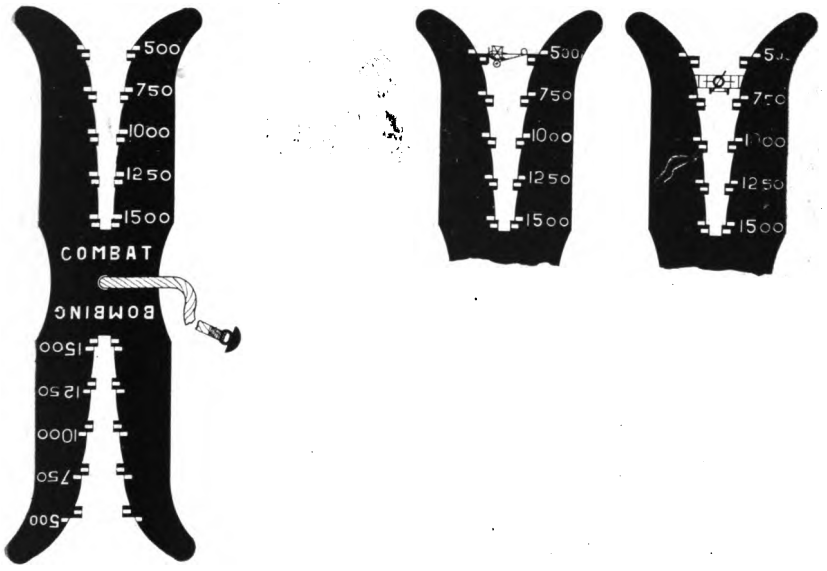
PLATE LII



THE STADIA, PEYCRU, COMPLETE AND SEPARATE VIEW ILLUSTRATING APPEARANCE OF AIRCRAFT AS VIEWED THROUGH STADIA.

124565—20——10

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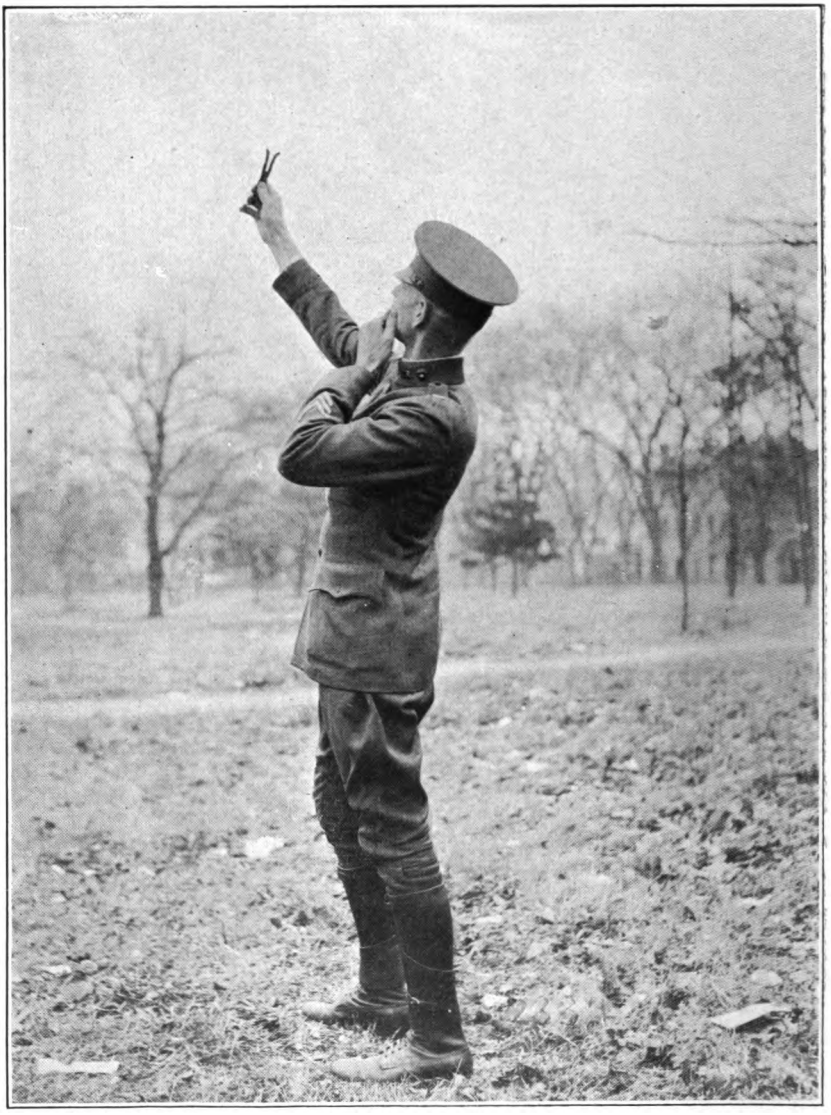

OFFICER APPROXIMATING DISTANCE OF AIRPLANE BY MEANS OF THE STADIA.

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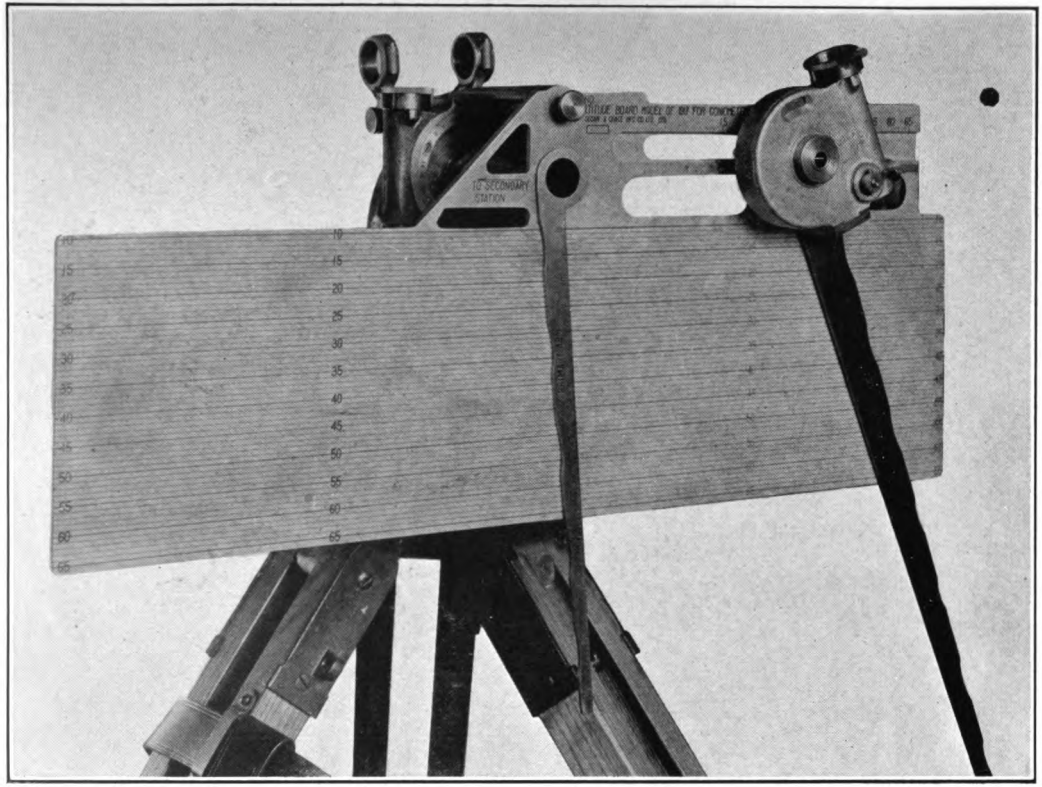
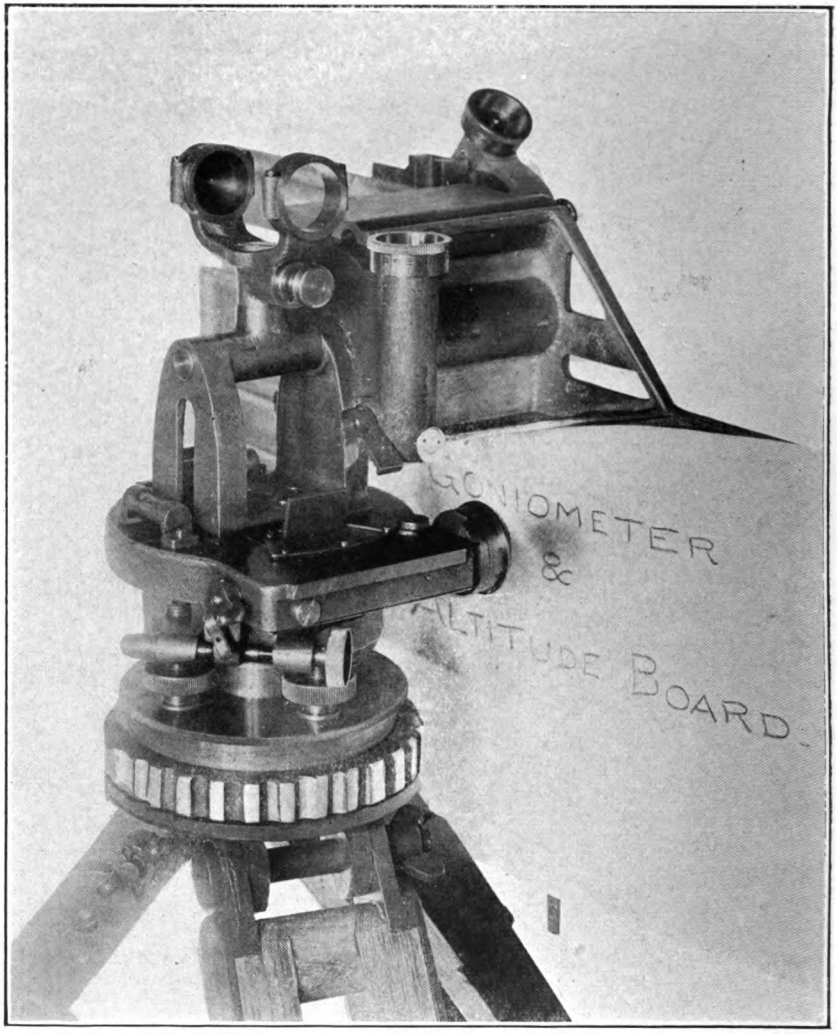


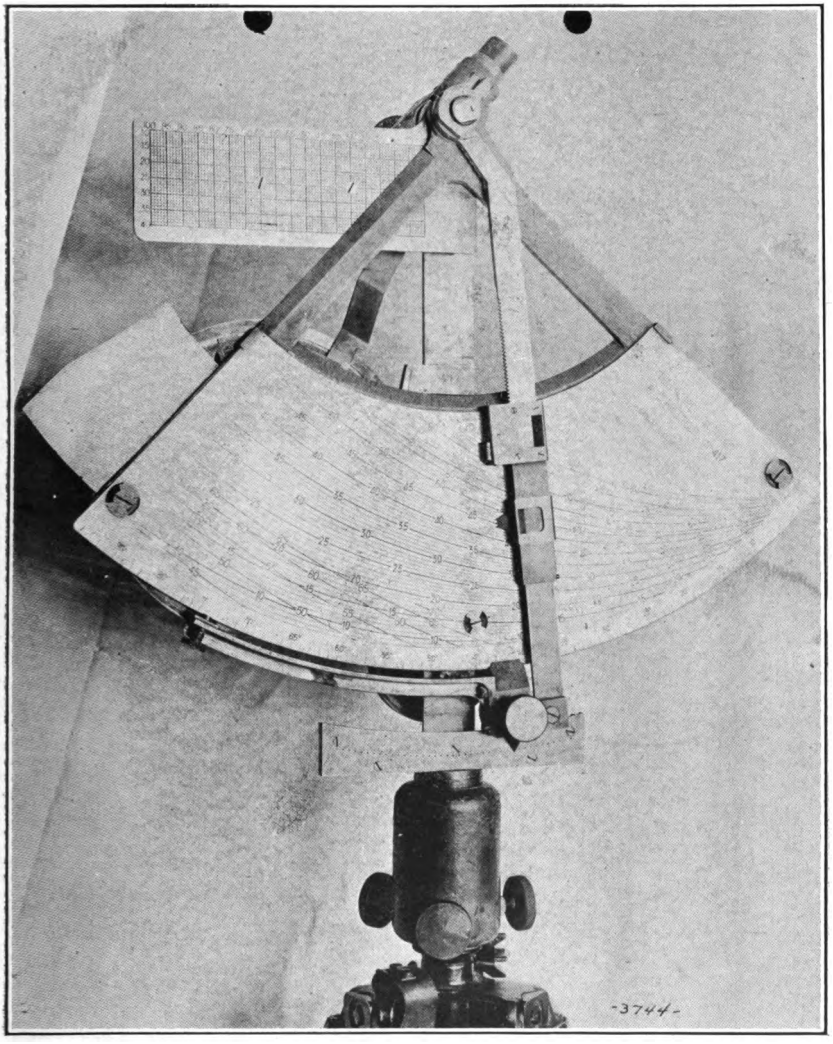
ALTITUDE BOARD, MODEL OF 1917, FOR GONIOMETER.

Digitized by Google



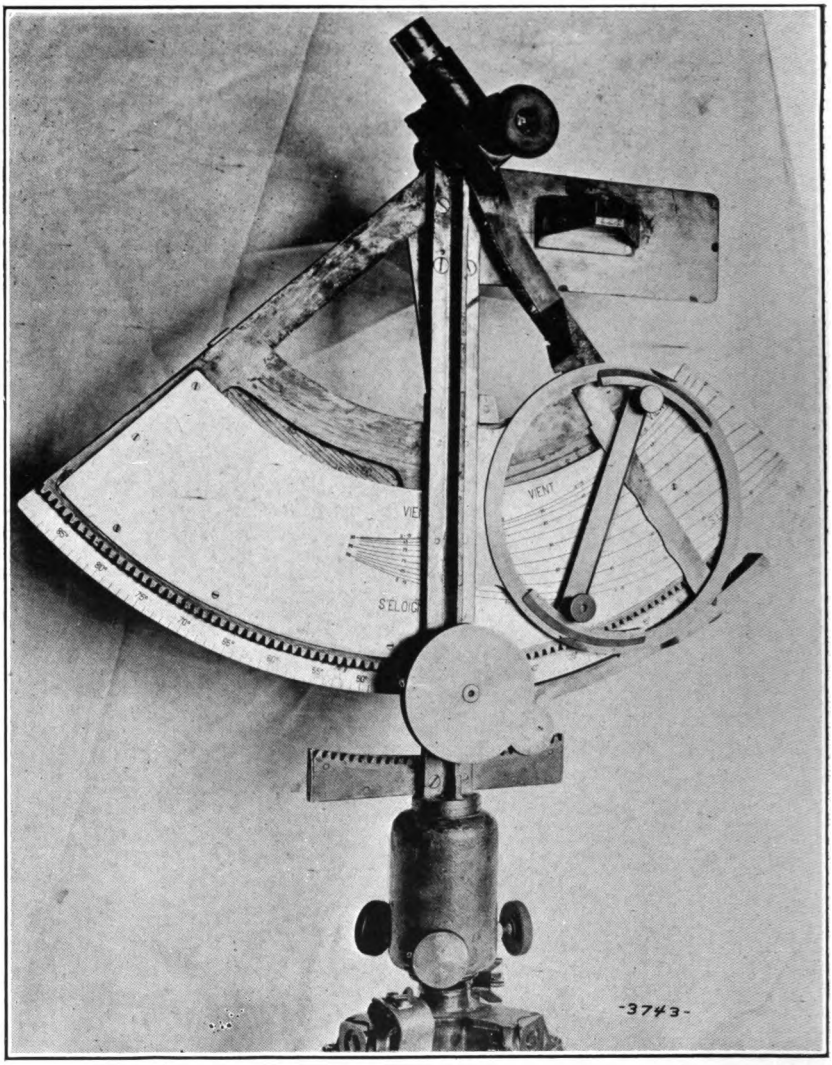
GONIOMETER AND ALTITUDE BOARD.

Digitized by Google



ALTITUDE TELEMETER, FRENCH TYPE. FRONT VIEW.

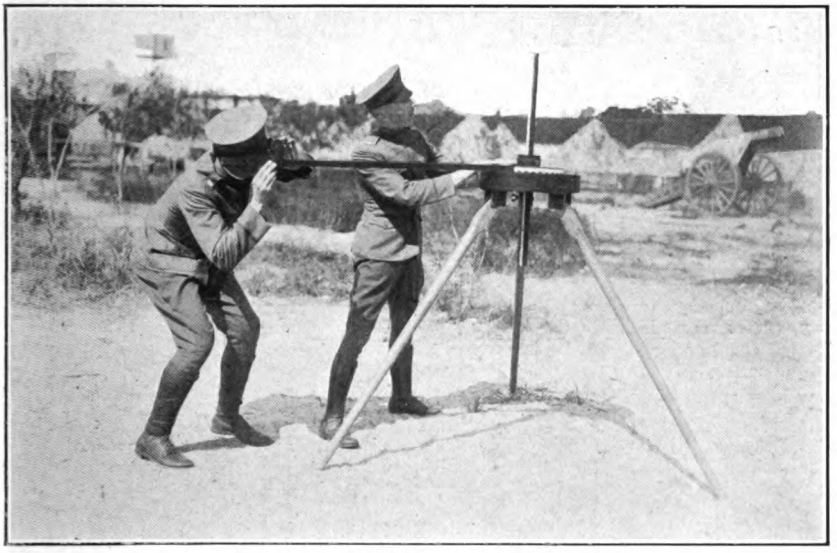
Digitized by Google



ALTITUDE TELEMETER, FRENCH TYPE. REAR VIEW.

Digitized by Google

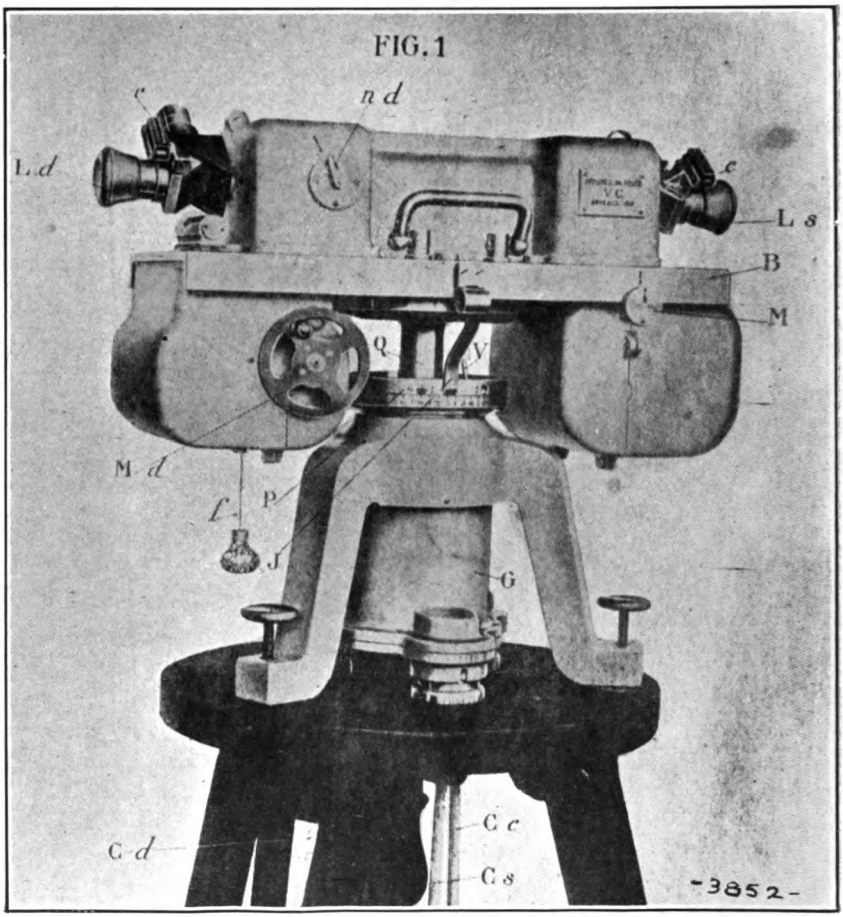
PLATE LVIII



STARTING WITH THE TACHYSCOPE.

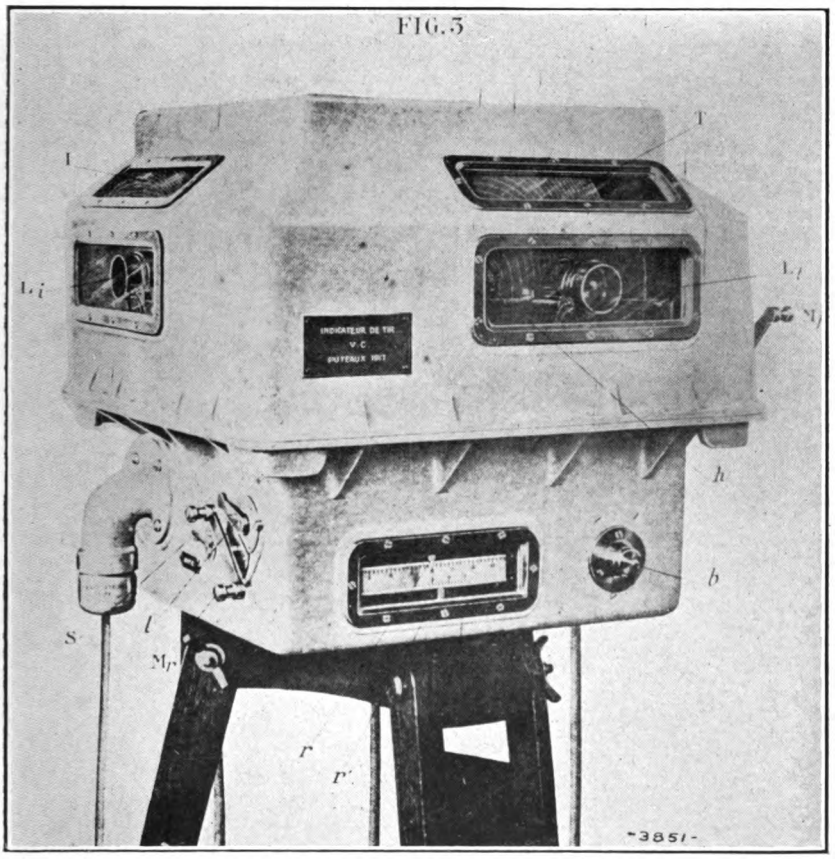
This instrument registers speed of target and direction in which it is bound.

Digitized by Google



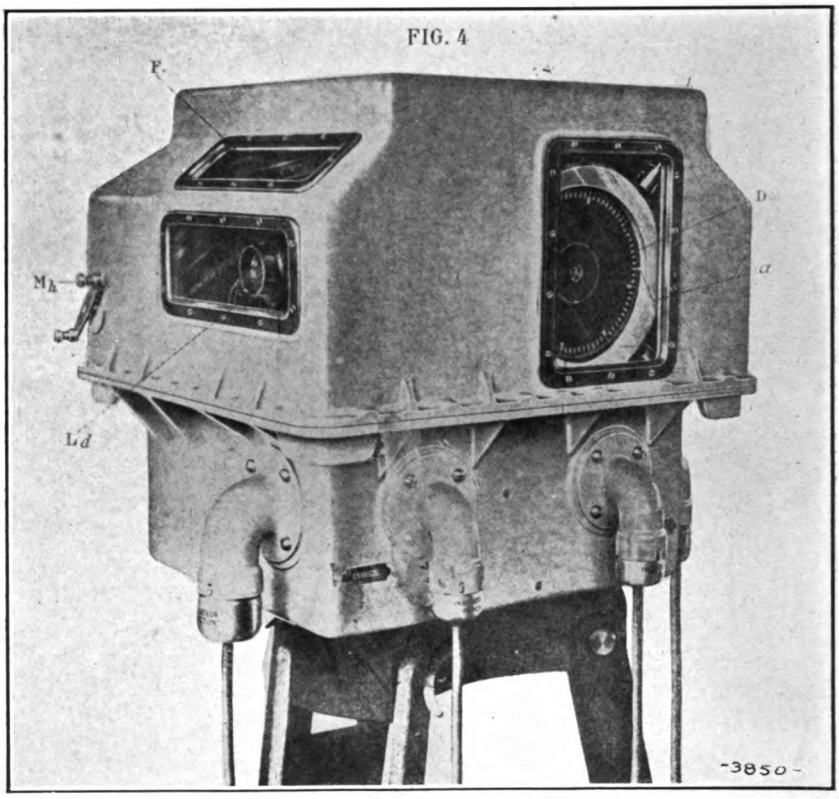
CORRECTOR V. C. OBSERVER'S STATION INSTRUMENT.

Digitized by Google



CORRECTOR V. C. CENTRAL STATION INSTRUMENT.

Digitized by Google



CORRECTOR V. C. CENTRAL STATION INSTRUMENT.

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AMERICAN GUNNER IN SECOND-LINE DEFENSES, MONTDIDIER FRONT, FIRING AT GERMAN AIRPLANES, NORTHEAST OF VILLERS, TOURNEVILLE, FRANCE, MARCH 20, 1918. HOTCHKISS MACHINE GUN WITH SERVICE SIGHT, MOUNTED ON UPPER SECTION OF HOTCHKISS TRIPOD ON GUYED WOODEN POST.

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HOTCHKISS MACHINE GUN WITH P. B. SIGHT, MOUNTED ON UPPER PART OF HOTCHKISS SERVICE TRIPOD AND REVOLVABLY SET IN TOP OF WOODEN POST. SHOWS ANOTHER SOLDIER ESTIMATING DISTANCE OF AIRPLANE BY MEANS OF THE STADIA RANGE INDICATOR. USED BY 322D ARTILLERY, BATTERY C, 83D DIVISION, AND AS ANTI-AIRCRAFT GUN GUARDING AMMUNITION.

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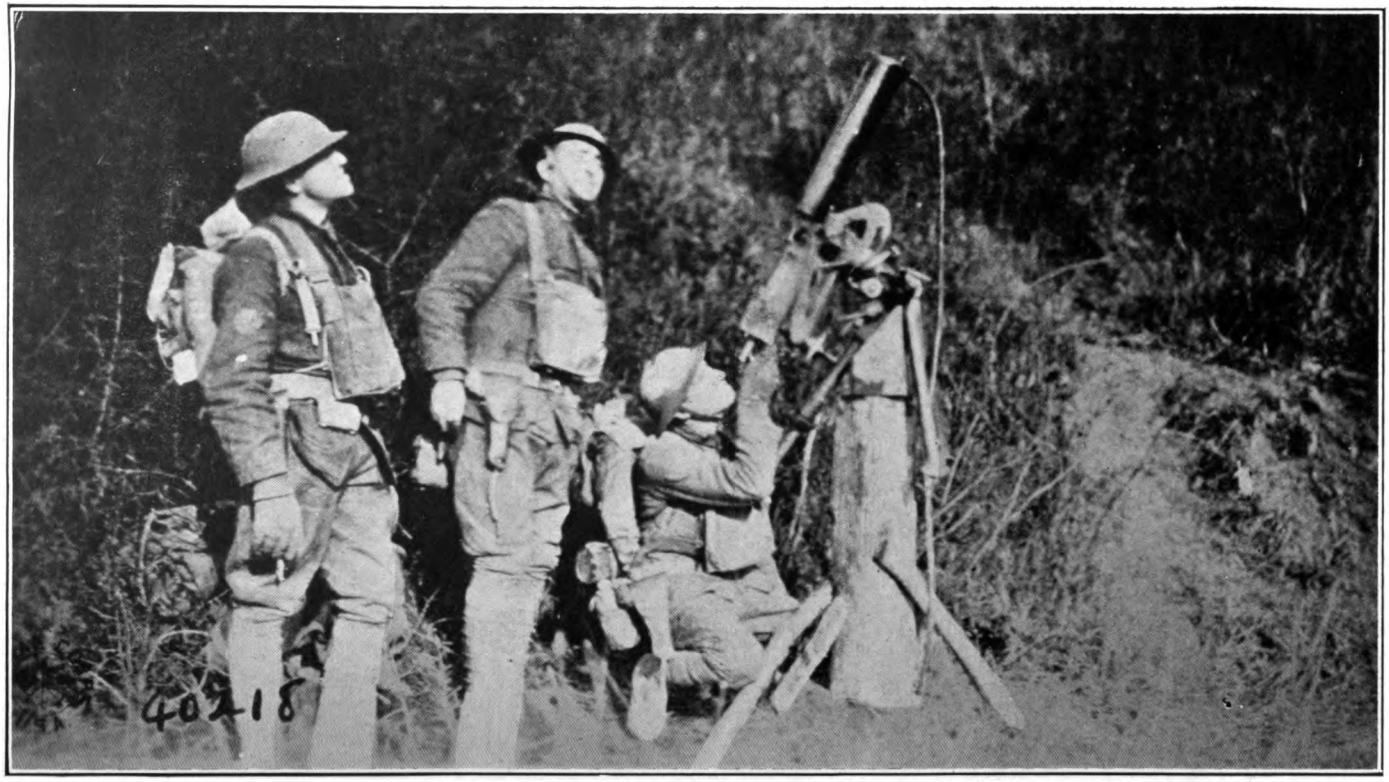
HOTCHKISS MACHINE GUN, STRIP FED, SERVICE SIGHT, ON MOUNT IMPROVISED BY LASHING LEGS OF TRIPOD TO WOODEN POST. LOCATION, DEATH VALLEY, BOIS BELLEAU, NEAR BATTERY 155S OF 103D FIELD ARTILLERY, 26TH DIVISION, HAUTMONT, MEUSE, FRANCE, OCTOBER 27, 1918.

Digitized by Google



BROWNING MACHINE GUN, WATER-COOLED, WITH SERVICE TRIPOD AND SERVICE SIGHT. TRIPOD SET ON POST TO PROVIDE HEIGHT FOR CONVENIENCE OF OPERATOR.

Getting ready to fire at enemy planes near Hautmont, Meuse, France.

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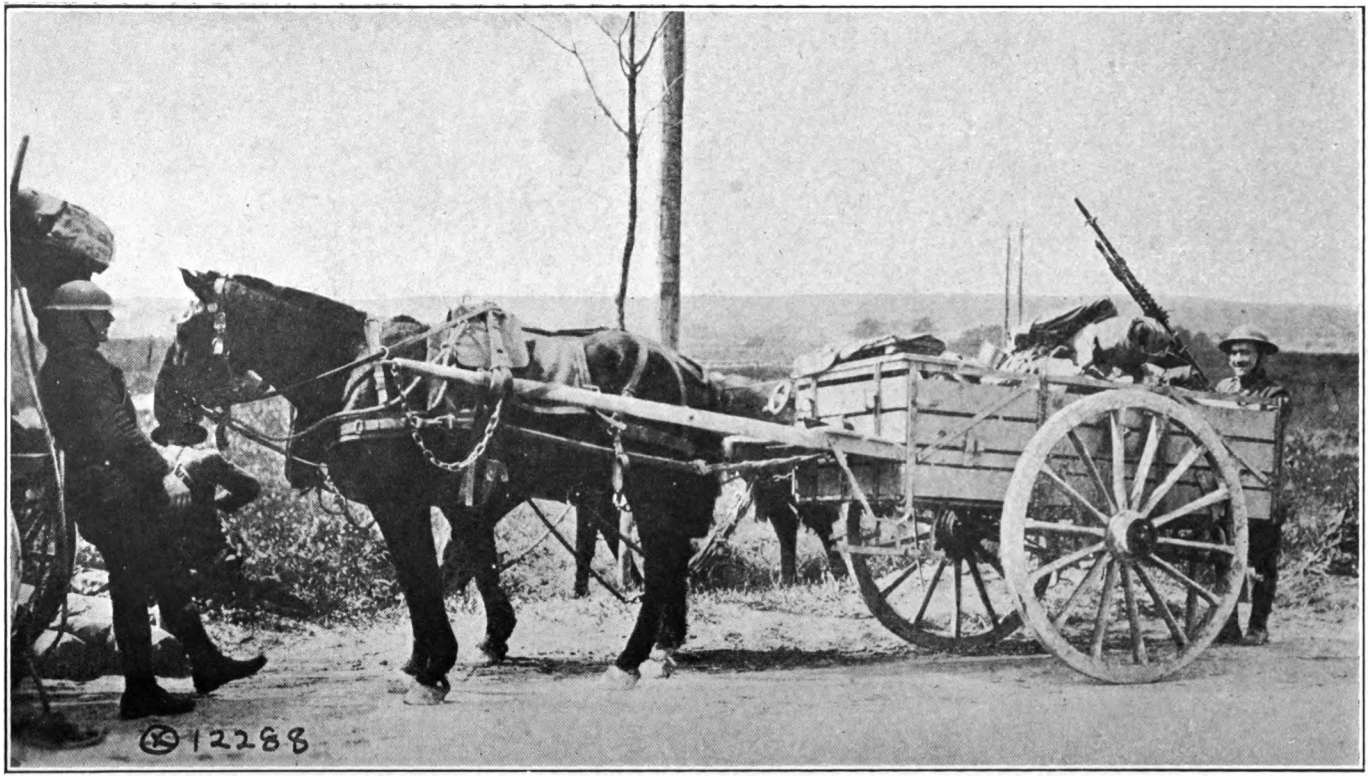
HOTCHKISS MACHINE GUN WITH SERVICE SIGHT, MOUNTED ON RIM OF WAGON WHEEL WITH VERTICAL AXIS. COMBINATION USED AS TEMPORARY EXPEDIENT FOR ANTI-AIRCRAFT WORK, BATTERY E, 6TH FIELD ARTILLERY, MENIL-LA-TOUR, FRANCE, FEBRUARY 17, 1918.

Digitized by Google



HOTCHKISS MACHINE GUN MOUNTED ON REAR OF HORSE CART, FOR ANTI-AIRCRAFT SERVICE, CHENEVIERES, FRANCE, APRIL 26, 1918, 1ST BATTALION, 149TH REGIMENT, FIELD ARTILLERY.

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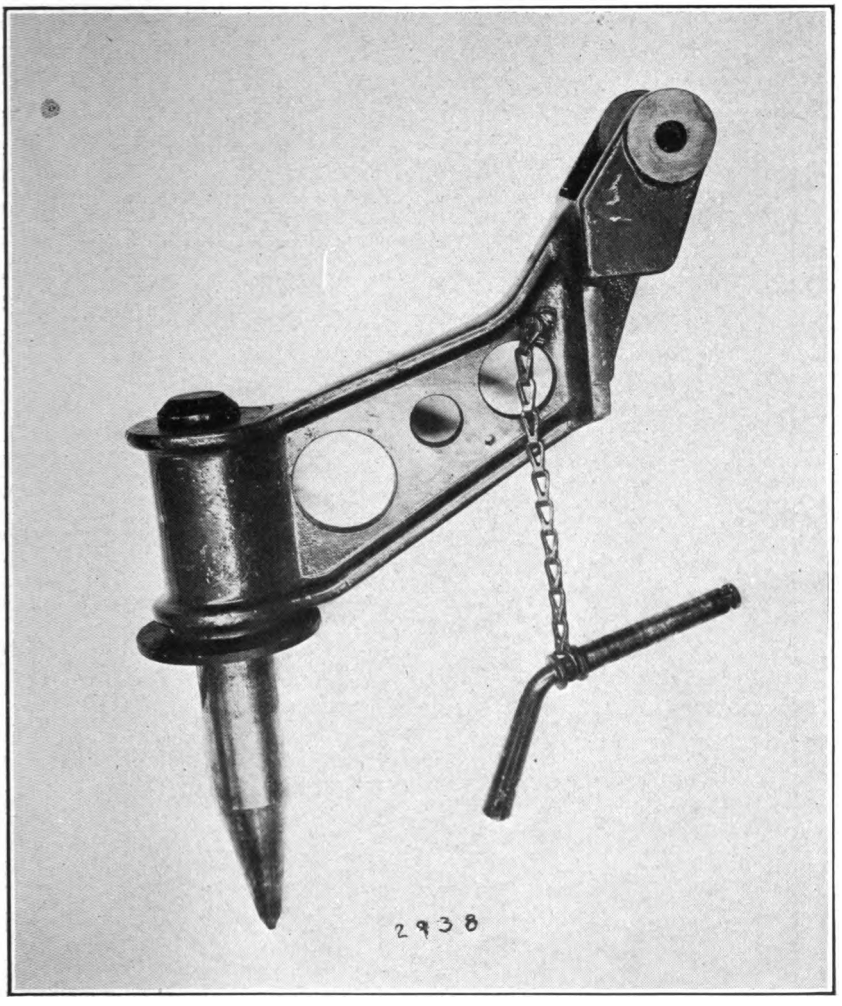
PLATE LXVIII



ANTI-AIRCRAFT IMPROVISED POST MOUNT, ASSEMBLED.

124565—20——11

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OMNIBUS TRIPOD, MODEL 1915, WITH ANTI-AIRCRAFT ADAPTER (FOREIGN DESIGN AND MANUFACTURE) AND HOTCHKISS MACHINE GUN.

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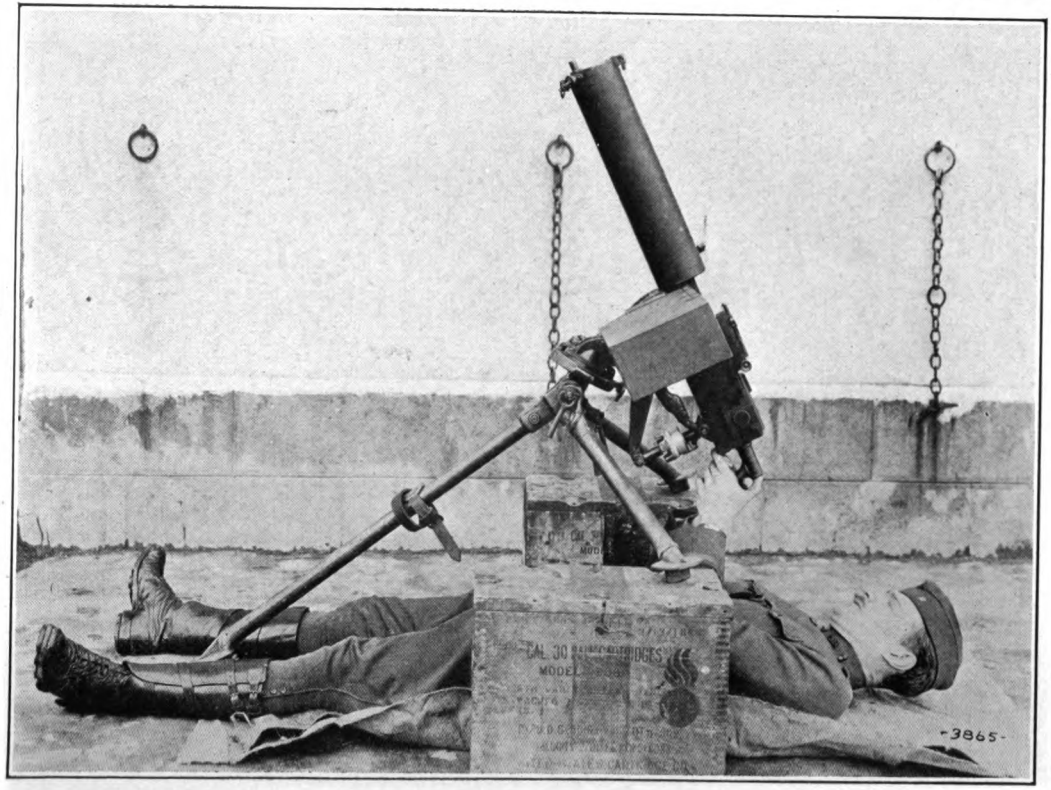
HOTCHKISS MACHINE GUN, STRIP FED, MOUNTED IN TRENCHES, FOR ANTI-AIRCRAFT WORK. SERVICE TRIPOD WITH ADAPTER BOLTED TO TRIPOD HEAD TO PERMIT HIGH ELEVATION. OPERATED BY SOLDIER LYING ON GROUND UNDER TRIPOD, WITH ANOTHER SOLDIER ATTENDING TO THE CARTRIDGE STRIPS. USED BY COMPANY C, 129TH MACHINE GUN BATTALION, FORMERLY 2D BATTALION, 2D REGIMENT, INFANTRY, MISSOURI NATIONAL GUARD, CAMP JORDAN, NEAR AMPHERSBACH, ALSACE, AUGUST 30, 1918.

Digitized by Google



BROWNING MACHINE GUN, MODEL OF 1917, ON CYGNET TRIPOD WITH SERVICE SIGHT.

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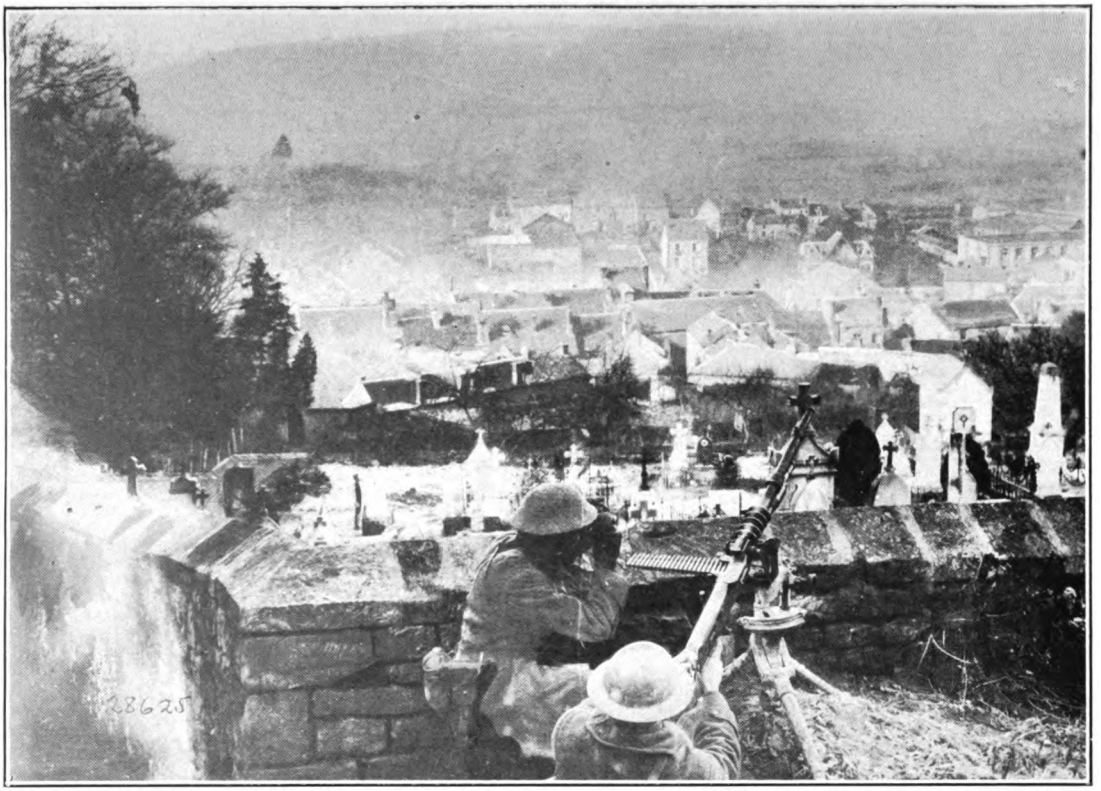

ANTI-AIRCRAFT POST OF 304TH MACHINE GUN BATTALION AT RAUCOURT, ARDENNES, FRANCE, HEADQUARTERS OF 77TH DIVISION, NOVEMBER 10, 1918. HOTCHKISS GUN, STRIP FED, MOUNTED ON SERVICE TRIPOD AND USING SERVICE SIGHT.

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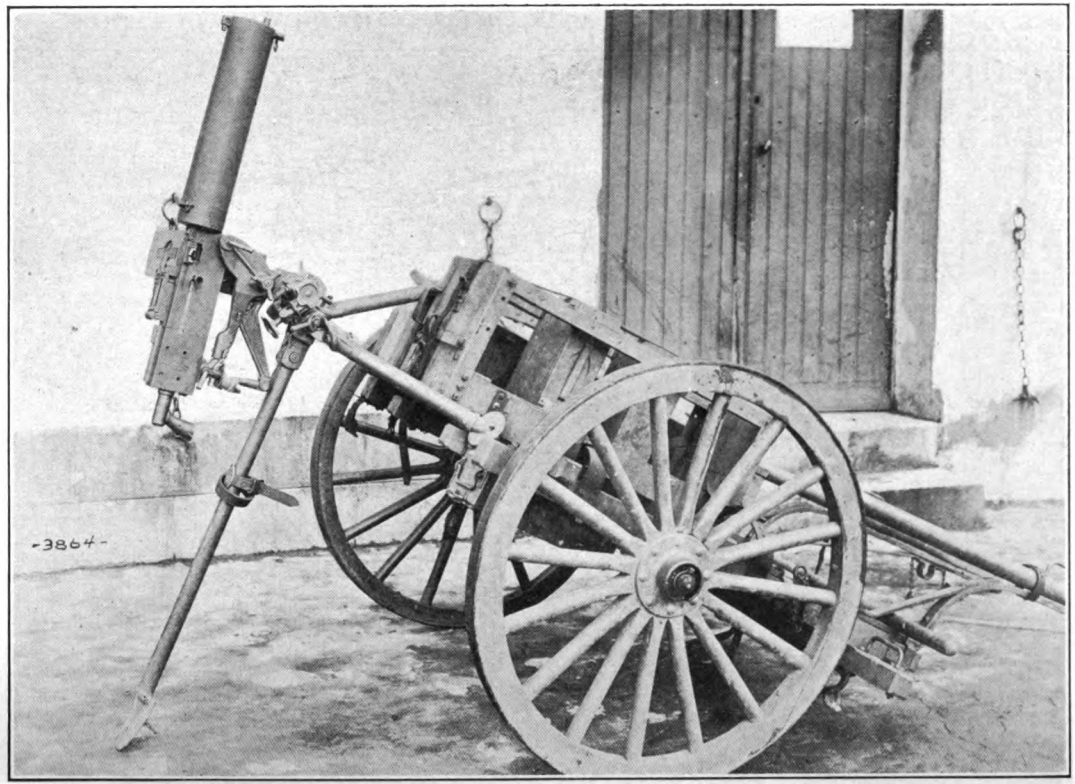

BROWNING MACHINE GUN, MODEL OF 1917, WITH SERVICE SIGHT, MOUNTED ON CYGNET TRIPOD, SERVICE TYPE, BRACED AGAINST AMMUNITION CART FOR ANTI-AIRCRAFT FIRE.

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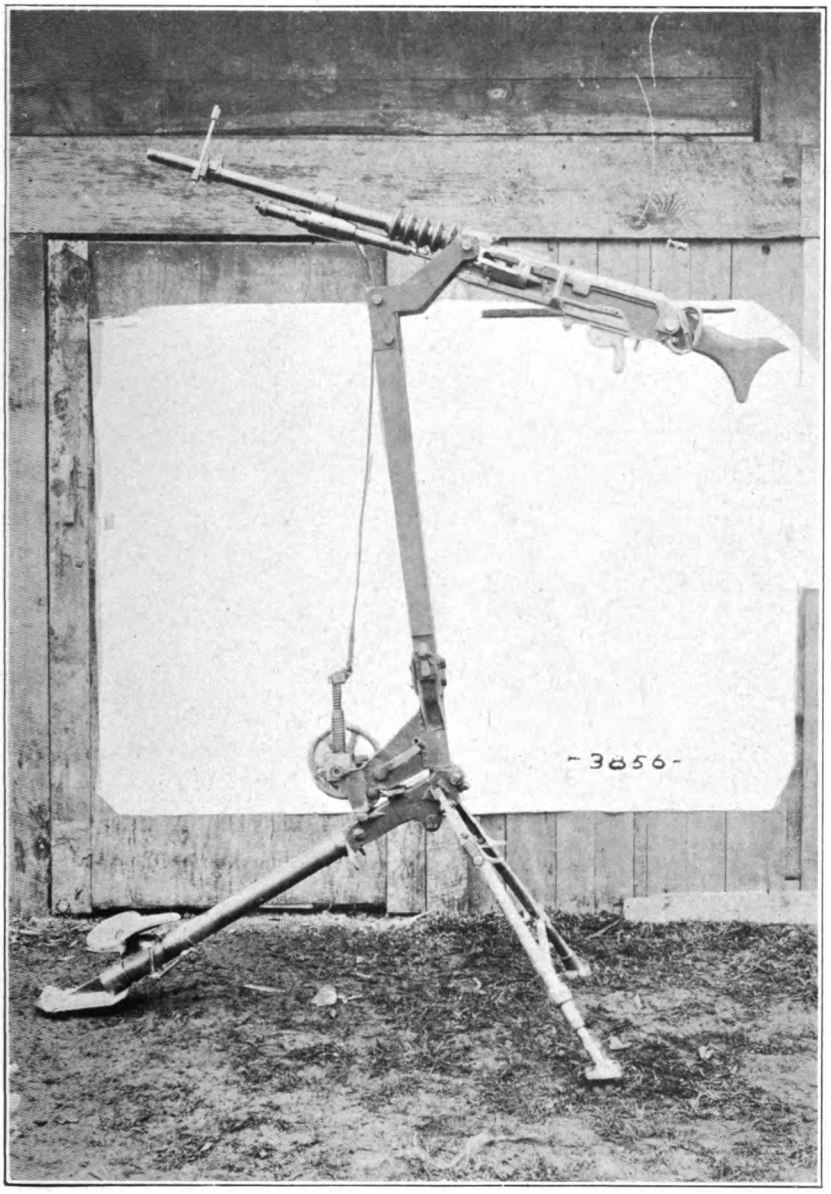

OMNIBUS TRIPOD, MODEL 1915, WITH SPECIAL ANTI-AIRCRAFT HIGH ADAPTER FOR ANTI-AIRCRAFT MOUNTED GUN BATTALIONS. HOTCHKISS GUN WITH AUXILIARY STOCK AND INFANTRY CORRECTOR SIGHT (FOREIGN DESIGN AND MANUFACTURE).

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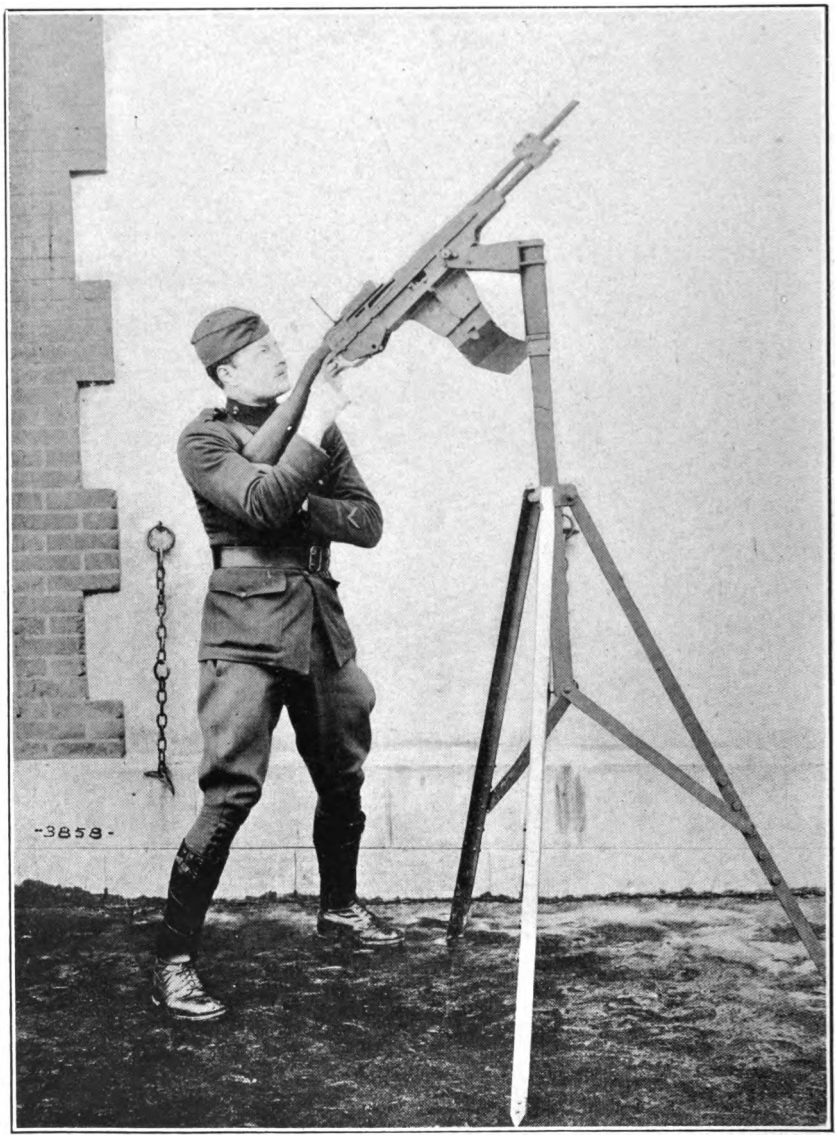

ANTI-AIRCRAFT MACHINE GUN A. E. F. HIGH TRIPOD, WITH ANTI-AIRCRAFT ADAPTER, USING MARLIN AIRCRAFT MACHINE GUN AND WITH ANTI-AIRCRAFT STOCK AND BROWNING AMMUNITION BOX.

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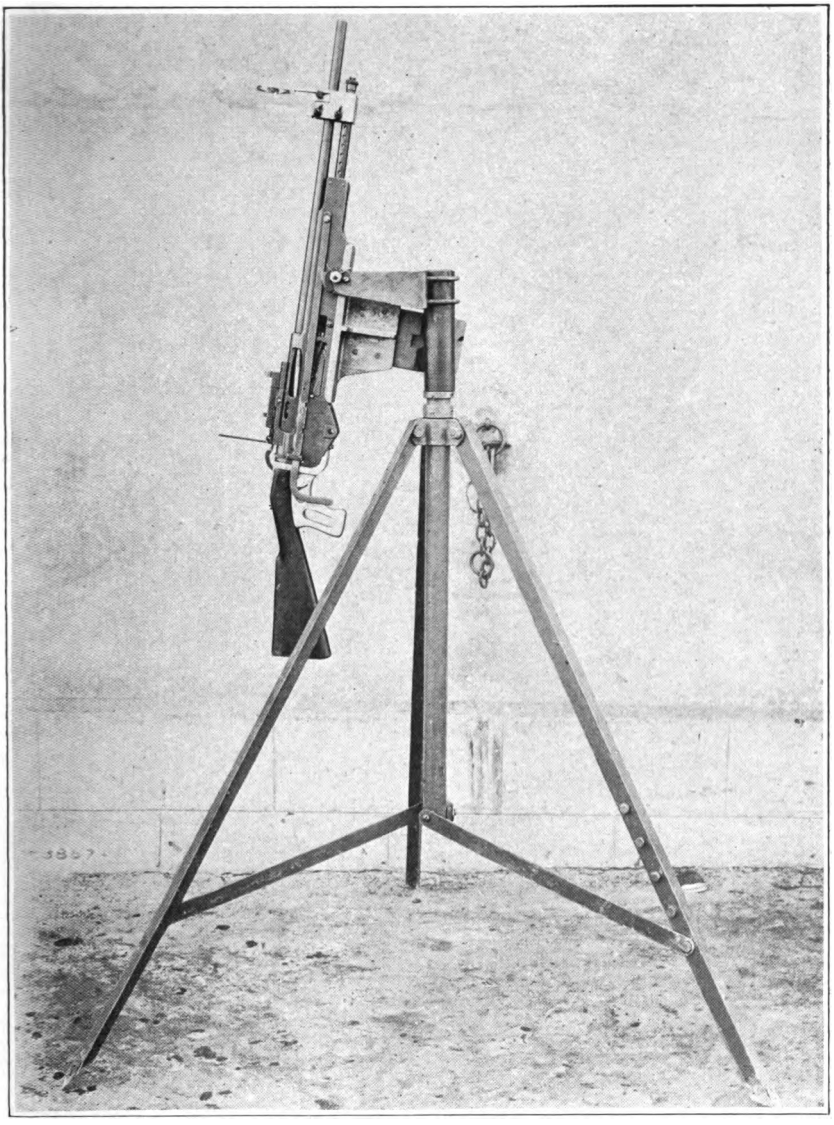

ANTI-AIRCRAFT MACHINE GUN A. E. F. HIGH TRIPOD, WITH ANTI-AIRCRAFT ADAPTER, USING MARLIN AIRCRAFT MACHINE GUN AND WITH ANTI-AIRCRAFT STOCK AND BROWNING AMMUNITION BOX; TRENCH OR FORWARD AREA SIGHT.

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ANTI-AIRCRAFT IMPROVISED POST MOUNT AS USED WITH MARLIN TANK MACHINE GUN WITH SHOULDER STOCK, TRENCH SIGHT, BROWNING AMMUNITION BOX WITH CARTRIDGE-BELT GUIDE.

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ANTI-AIRCRAFT MACHINE GUN TELESCOPIC TRIPOD (DISCARDED IN FAVOR OF THE ANTI-AIRCRAFT MACHINE GUN TRIPOD, MODEL OF 1918), SHOWN WITH LEWIS MACHINE GUN USING TRENCH (FOR FORWARD AREA) SIGHT AND LEWIS ADAPTER.

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ANTI-AIRCRAFT MACHINE GUN TRIPOD, MODEL OF 1918, AS USED WITH VICKERS MACHINE GUN, MODEL OF 1915, WITH P. B. AIM CORRECTOR SIGHT (NOW DISCARDED IN FAVOR OF PEYCRU SIGHT), WITH SHOULDER STOCK, BROWNING AND VICKERS ADAPTER, VICKERS AMMUNITION BOX IN CONTAINING BASKET WITH CARTRIDGE-BELT GUIDE.

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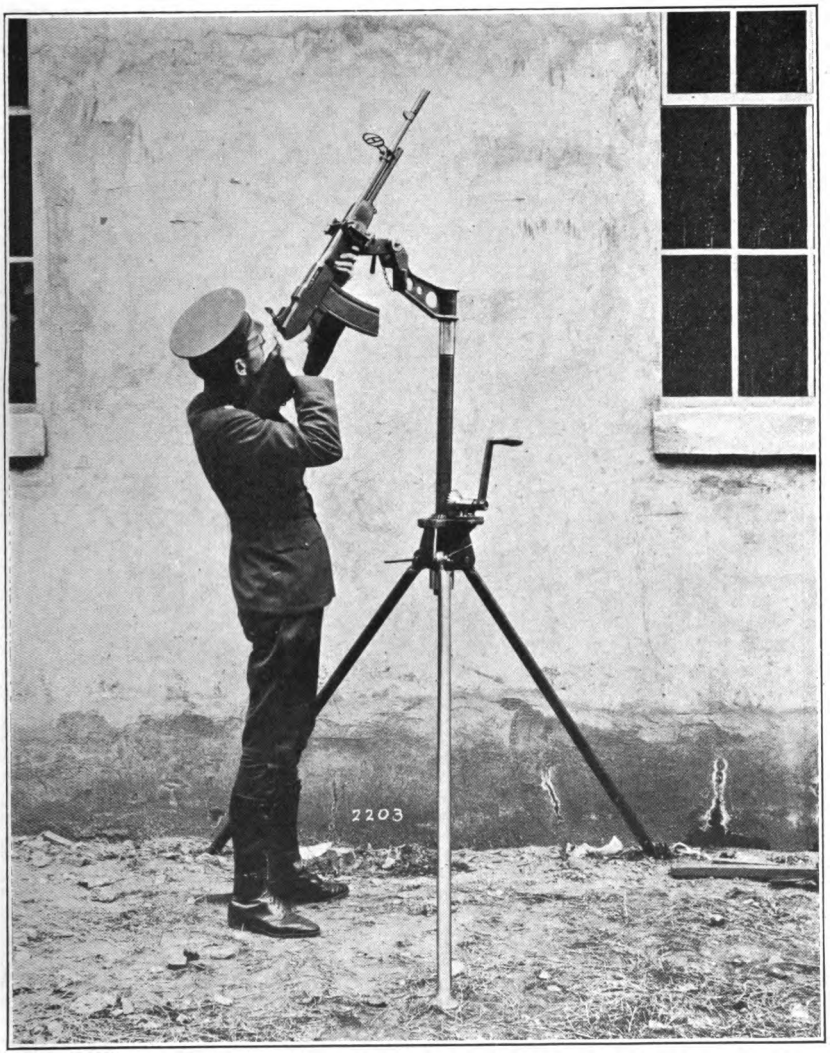

ANTI-AIRCRAFT MACHINE GUN TELESCOPIC TRIPOD (NOW DISCARDED IN FAVOR OF THE ANTI-AIRCRAFT MACHINE GUN TRIPOD, MODEL OF 1918), AS USED WITH BROWNING AUTOMATIC RIFLE WITH TRENCH SIGHT, BROWNING ADAPTER AND 40-ROUND MAGAZINE.

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ANTI-AIRCRAFT MACHINE GUN TRIPOD, MODEL 1918, AS USED WITH BROWNING MACHINE GUN (WATER-COOLED), MODEL OF 1917, WITH TRENCH SIGHT, BROWNING SHOULDER STOCK, BROWNING AND VICKERS ADAPTER, AND BROWNING AMMUNITION BOX.

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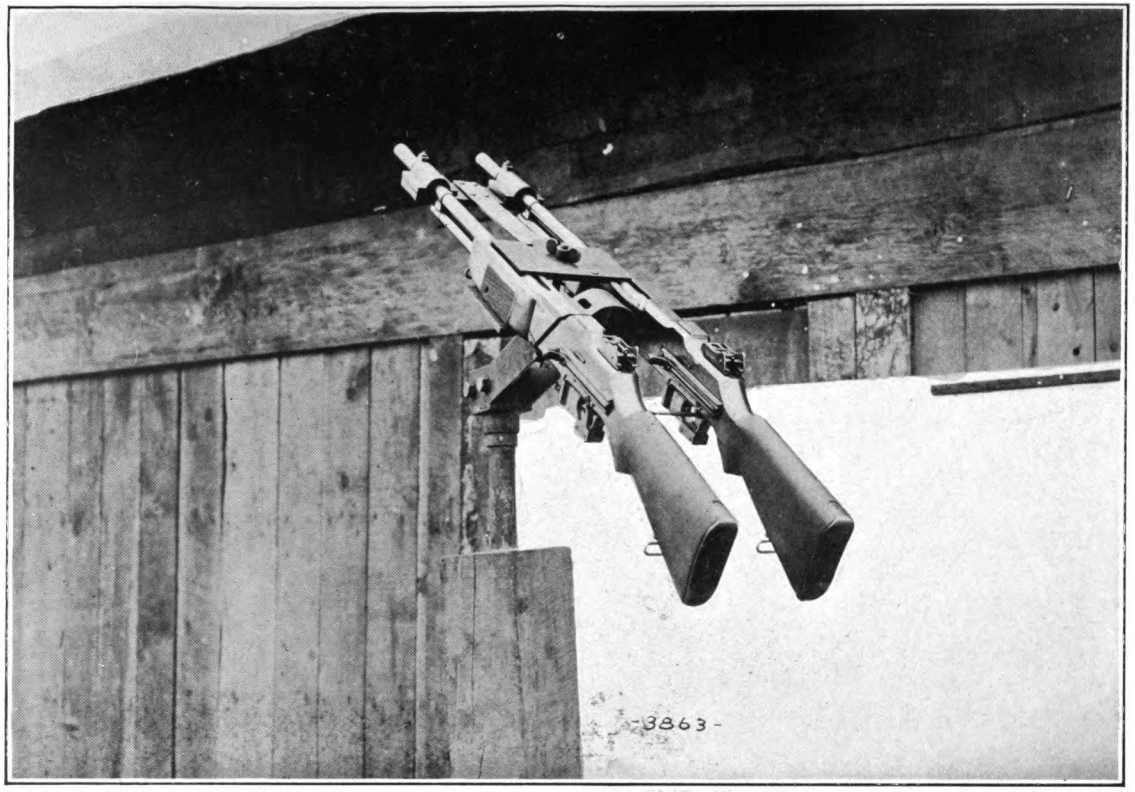

BROWNING AUTOMATIC RIFLES ARRANGED IN PAIR AND WITH CROSSBAR FOR SIMULTANEOUSLY OPERATING BOTH TRIGGERS, ON POST MOUNT FOR ANTI-AIRCRAFT FIRE.

Note shell deflector on left-hand rifle.

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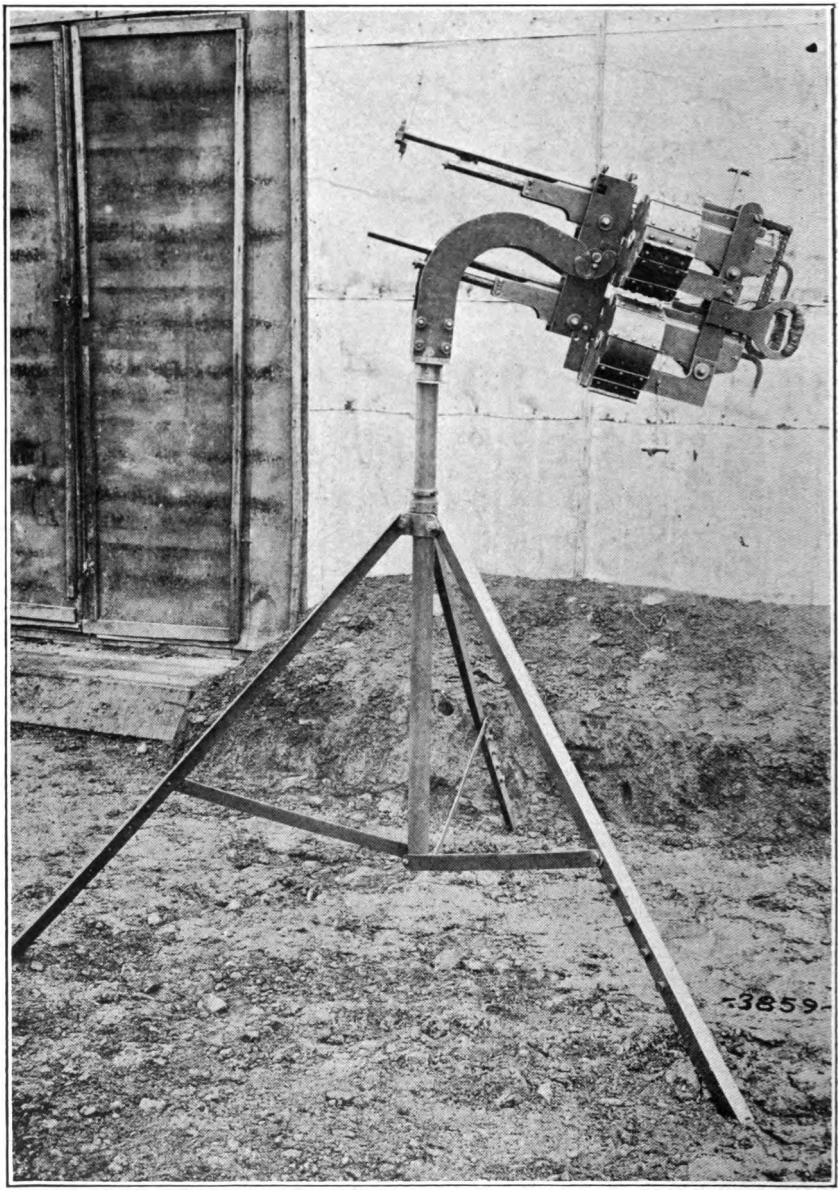

MARLIN AIRCRAFT MACHINE GUNS ARRANGED IN PAIR AND MOUNTED ON ANTI-AIRCRAFT MACHINE GUN HIGH TRIPOD WITH SPECIAL HEAD.

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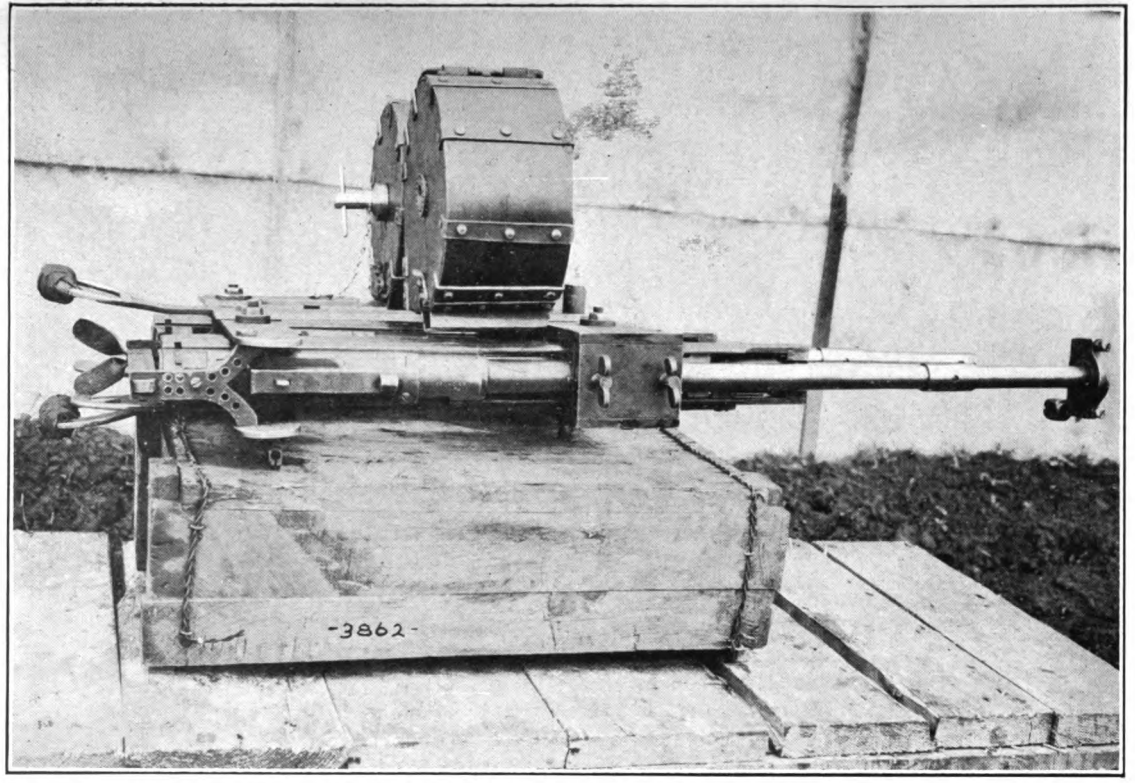

MARLIN AIRCRAFT MACHINE GUNS ARRANGED IN PAIR FOR ANTI-AIRCRAFT FIRE. TOP VIEW, SHOWING DRUM-SHAPED AMMUNITION FEED DEVICE.

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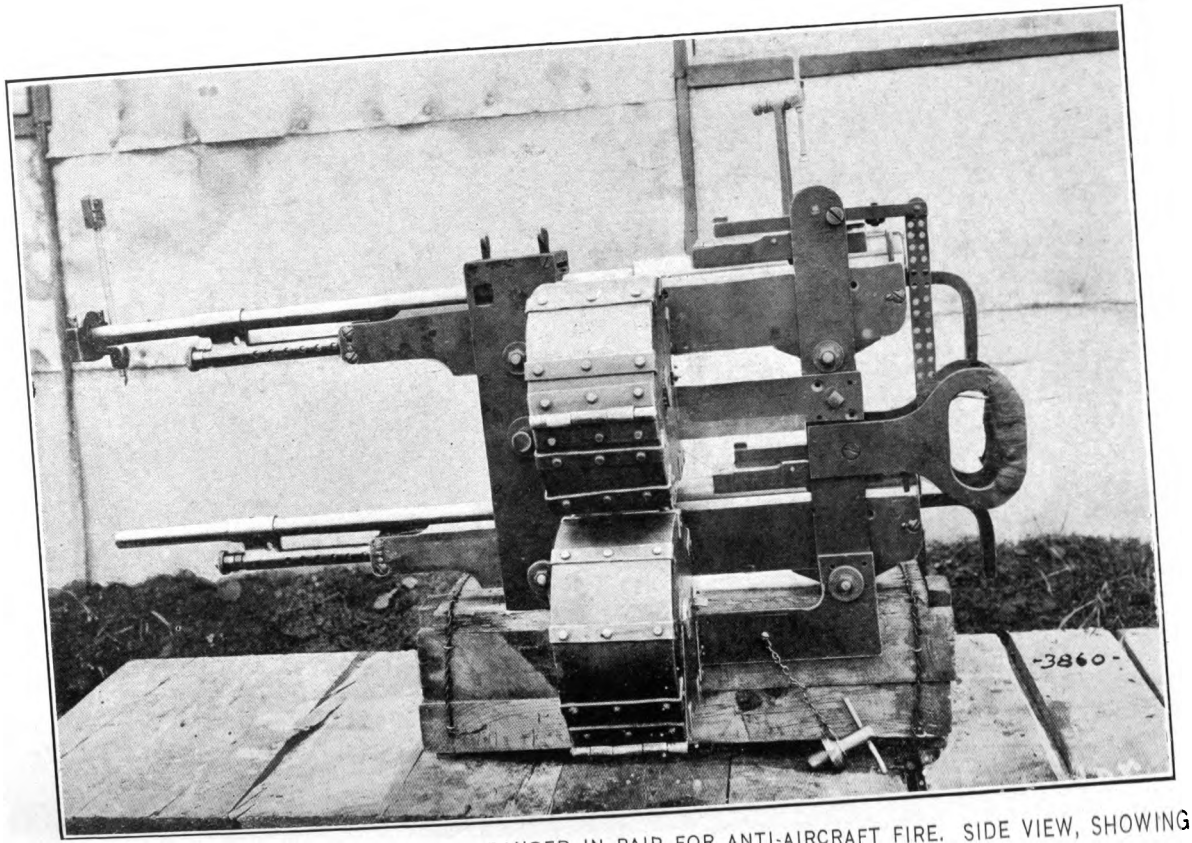

MARLIN AIRCRAFT MACHINE GUNS ARRANGED IN PAIR FOR ANTI-AIRCRAFT FIRE. SIDE VIEW, SHOWING AMMUNITION FEED DEVICE IN CLOSED POSITION. INFANTRY CORRECTOR SIGHT.

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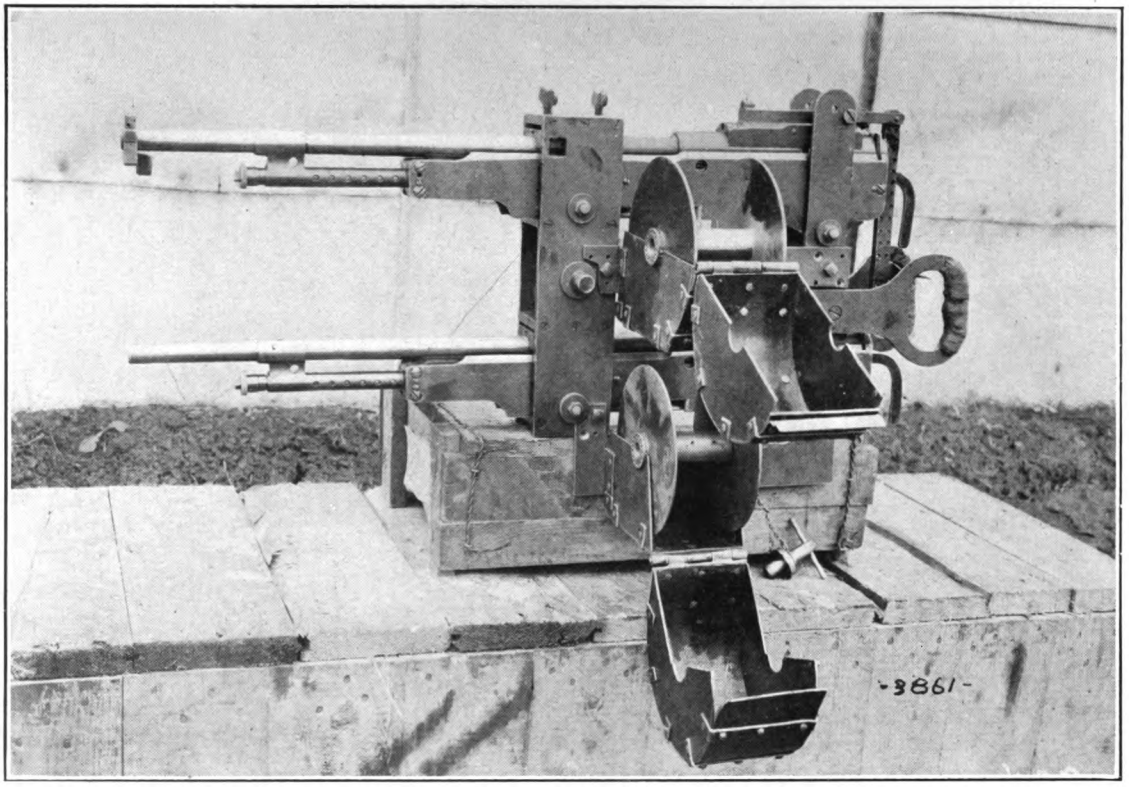

MARLIN AIRCRAFT MACHINE GUNS ARRANGED IN PAIR FOR ANTI-AIRCRAFT FIRE. SIDE VIEW, SHOWING AMMUNITION FEED DEVICE IN OPEN POSITION.

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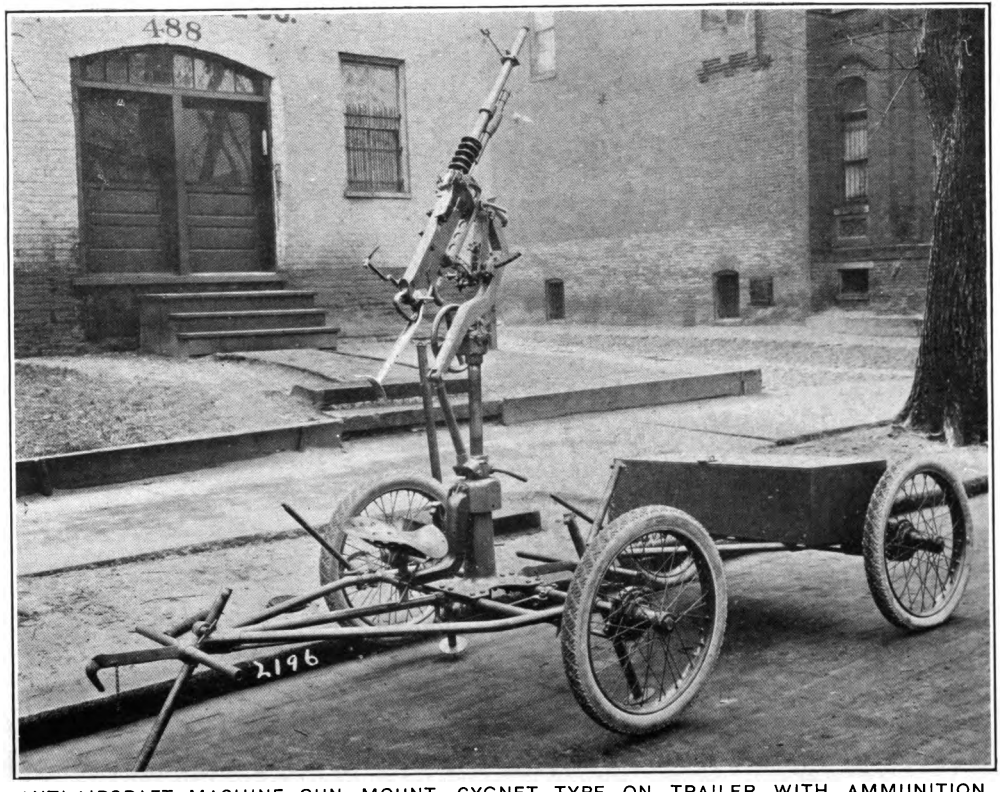

ANTI-AIRCRAFT MACHINE GUN MOUNT, CYGNET TYPE, ON TRAILER WITH AMMUNITION TRAILER, AS USED WITH HOTCHKISS MACHINE GUN, MODEL OF 1917, WITH P. B. SIGHT (NOW DISCARDED IN FAVOR OF PEYCRU SIGHT). HOTCHKISS SHOULDER STOCK AND HOTCHKISS ADAPTER.

This model trailer has since been improved.

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ANTI-AIRCRAFT MACHINE GUN MOUNT, CYGNET TYPE, ON TRAILER WITH AMMUNITION TRAILER, SHOWN WITH MARLIN TANK MACHINE GUN WITH TRENCH (FOR FORWARD AREA) SIGHT, BROWNING AMMUNITION BOX AND CARTRIDGE-BELT GUIDE.

This model trailer has been since improved.

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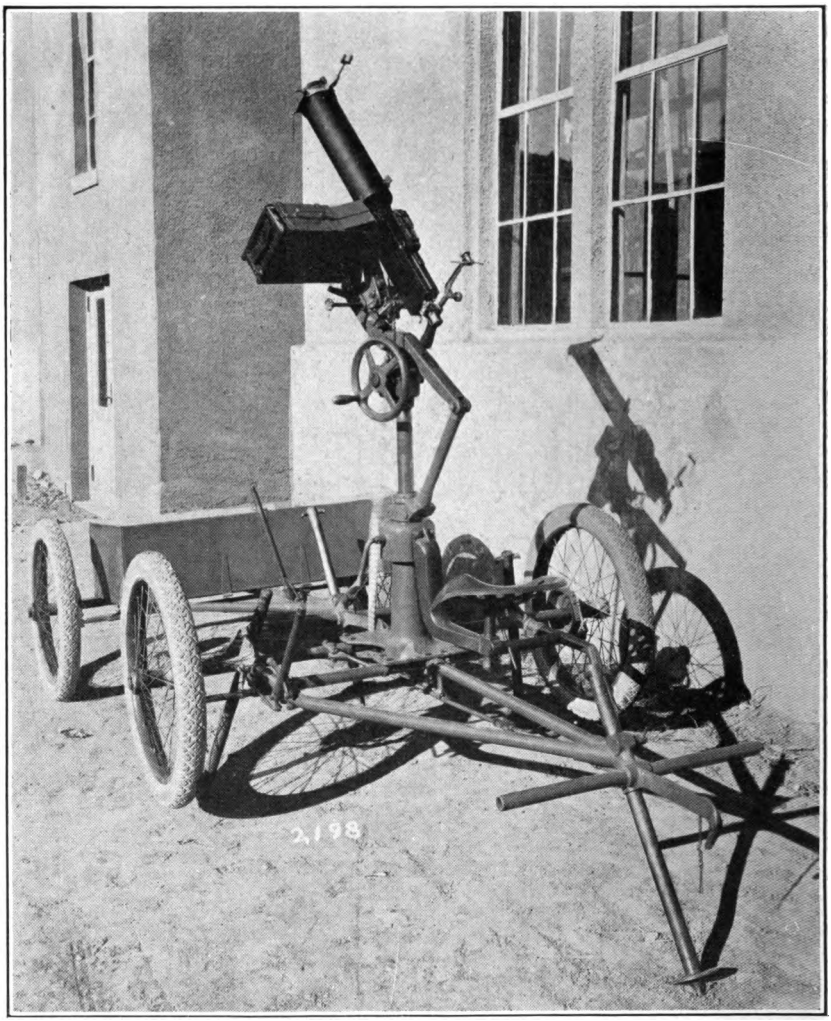
PLATE XCI



ANTI-AIRCRAFT MACHINE GUN MOUNT, CYGNET TYPE (THIS MOUNT HAS BEEN IMPROVED) ON TRAILER WITH AMMUNITION TRAILER, SHOWN WITH BROWNING MACHINE GUN WATER-COOLED, MODEL 1917, WITH P. B. AIM CORRECTOR SIGHT (NOW DISCARDED IN FAVOR OF PEYCRU SIGHT), EXPENDABLE AMMUNITION BOX, MARK I, AND CARTRIDGE-BELT GUIDE ON BOX.

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ANTI-AIRCRAFT MACHINE GUN TRAILER, MODEL 1918, SECHLER TYPE, WITH ANTI-AIRCRAFT MOUNT, CYGNET TYPE, AND ANTI-AIRCRAFT MACHINE GUN TRIPOD, MODEL 1918, WITH FRENCH ADAPTER AND WITH MACHINE GUN CHESTS AND SPARE PARTS CHEST.

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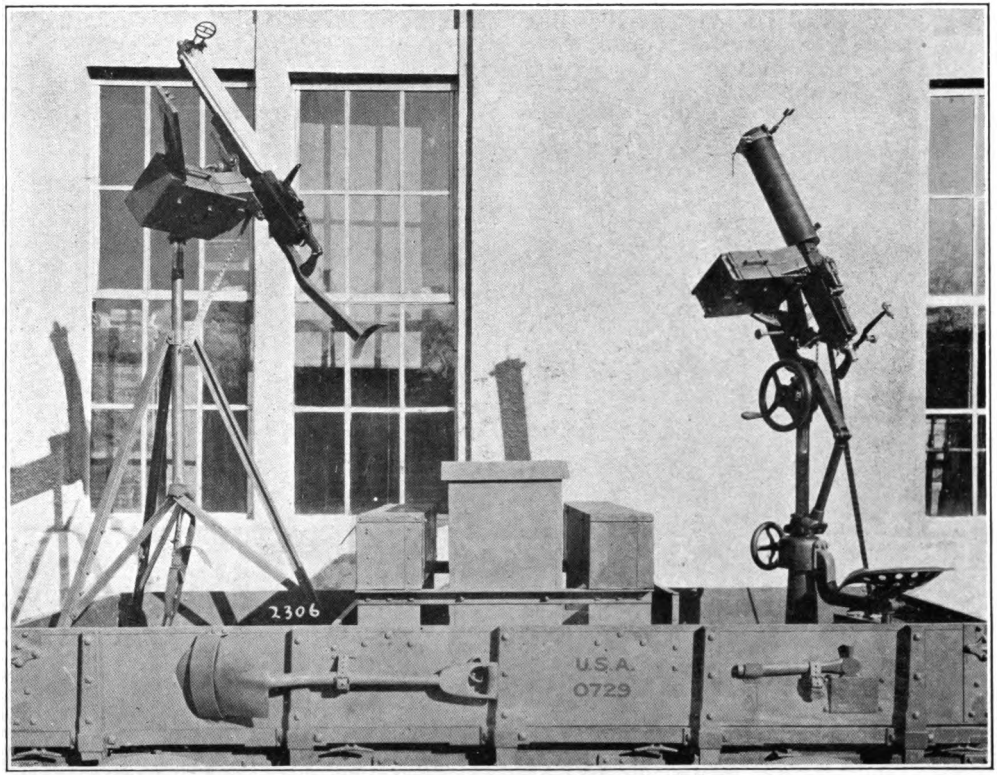

THE ANTI-AIRCRAFT MACHINE GUN TRAILER, MODEL OF 1918, SECHLER TYPE.

Body view. Showing also mounted thereon anti-aircraft machine-gun tripod, model of 1918 (this mount has been improved), with Marlin tank machine gun, trench sight, shoulder stock, Browning ammunition box, cartridge-belt guide on same, and anti-aircraft mount, Cygnet type, with Browning machine gun, model of 1917, and P. B. aim corrector sight (now discarded in favor of Peycru sight), expendable ammunition box, Mark I, with cartridge-belt guide. View shows gun chests and spare parts chest.

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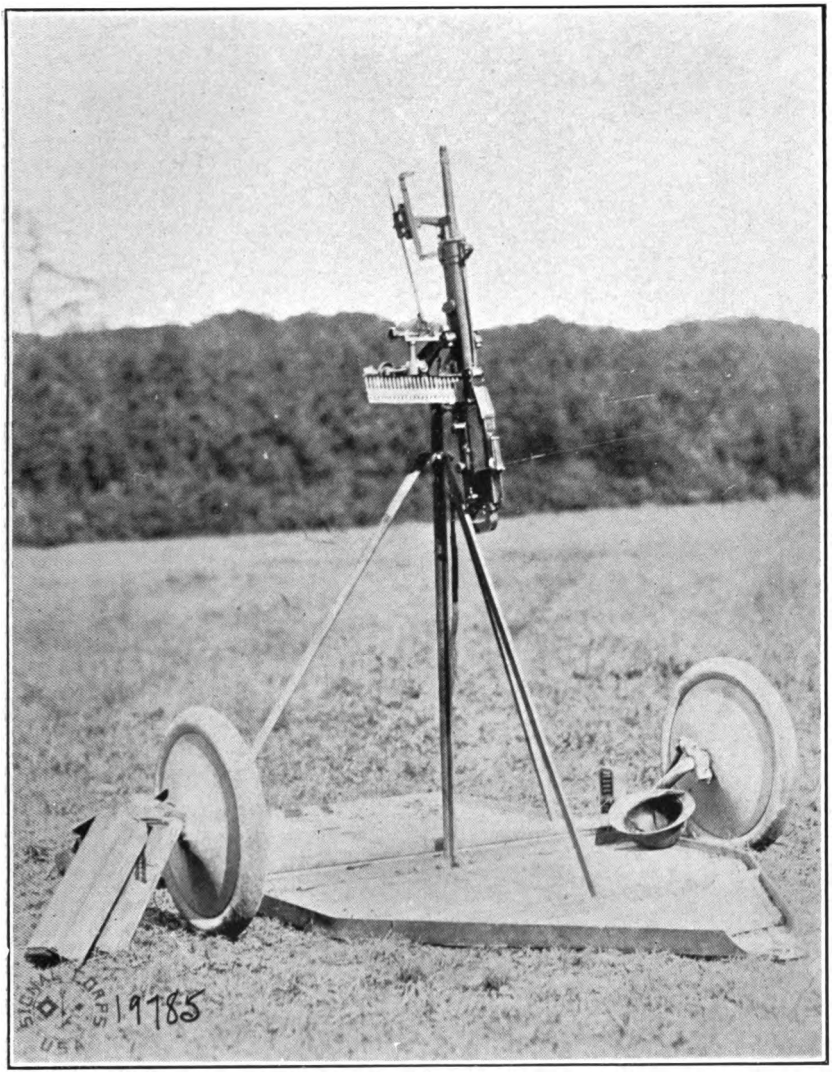

FRENCH MACHINE GUN IN ALSACE SECTOR, WITH FRENCH, JULY 30, 1918. HOTCHKISS TYPE GUN, STRIP FED, WITH AIRCRAFT SIGHT USED FOR ANTI-AIRCRAFT WORK.

Gun mounted on folding tripod, set on platform trailer with offset axle, which has been inverted and used as platform for firing.

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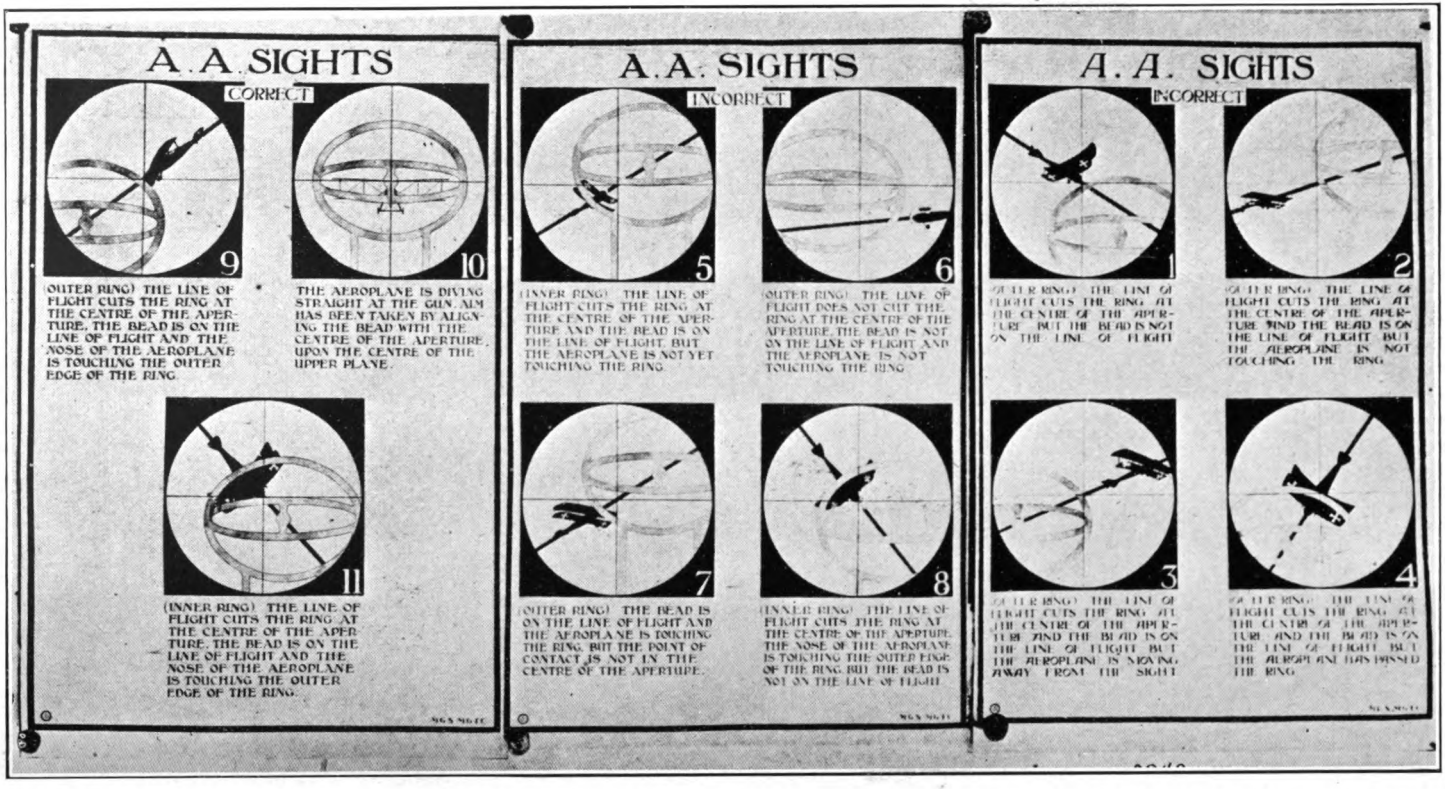

DIAGRAM SHOWING CORRECT AND INCORRECT SIGHTING BY MEANS OF TRENCH SIGHT OR FORWARD AREA SIGHT FOR MACHINE GUNS.

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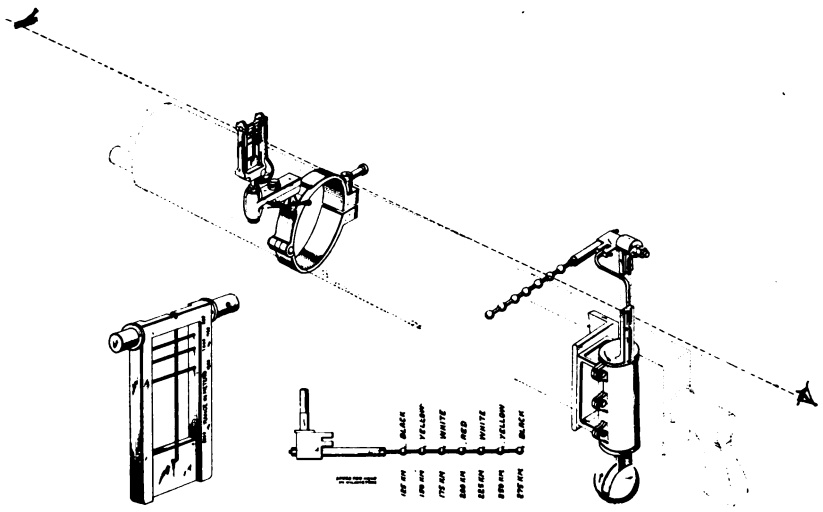

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PEYCRU SIGHT AS MOUNTED AND USED ON BROWNING MACHINE GUN, WATER-COOLED, MODEL OF 1917.

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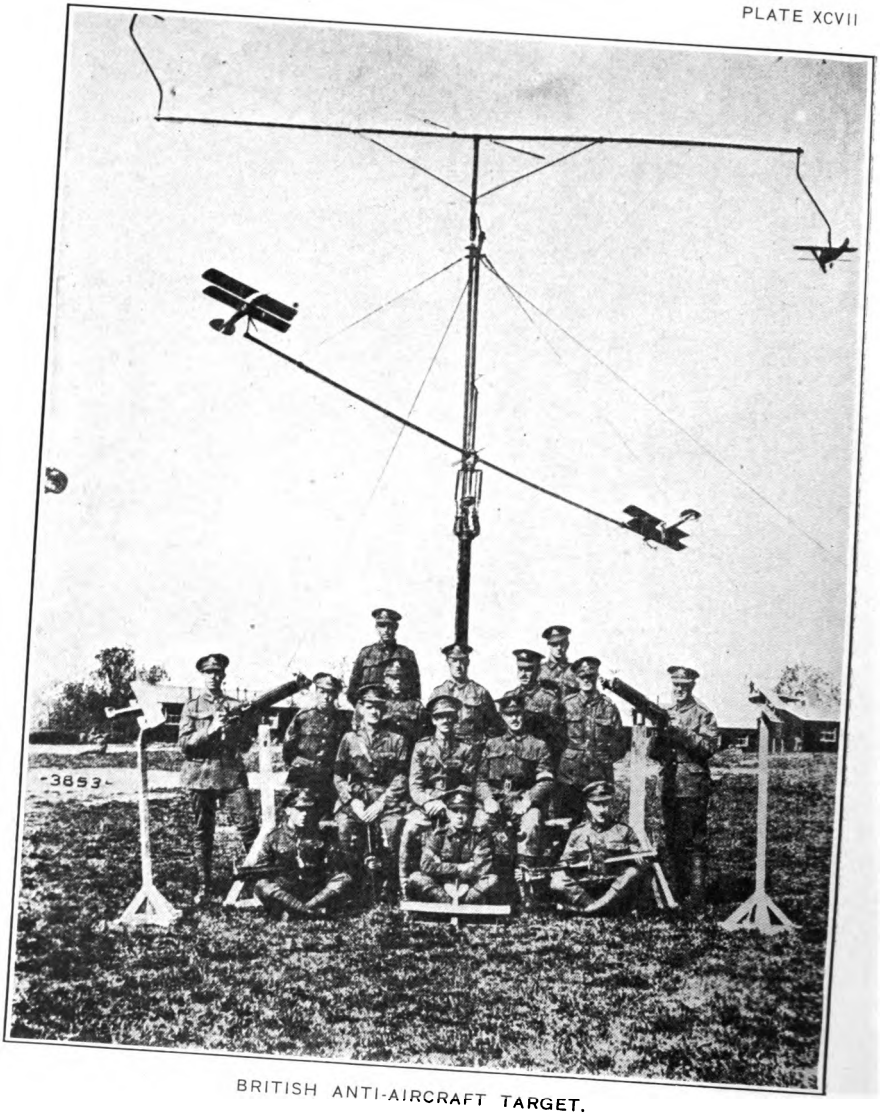

BRITISH ANTI-AIRCRAFT TARGET.

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